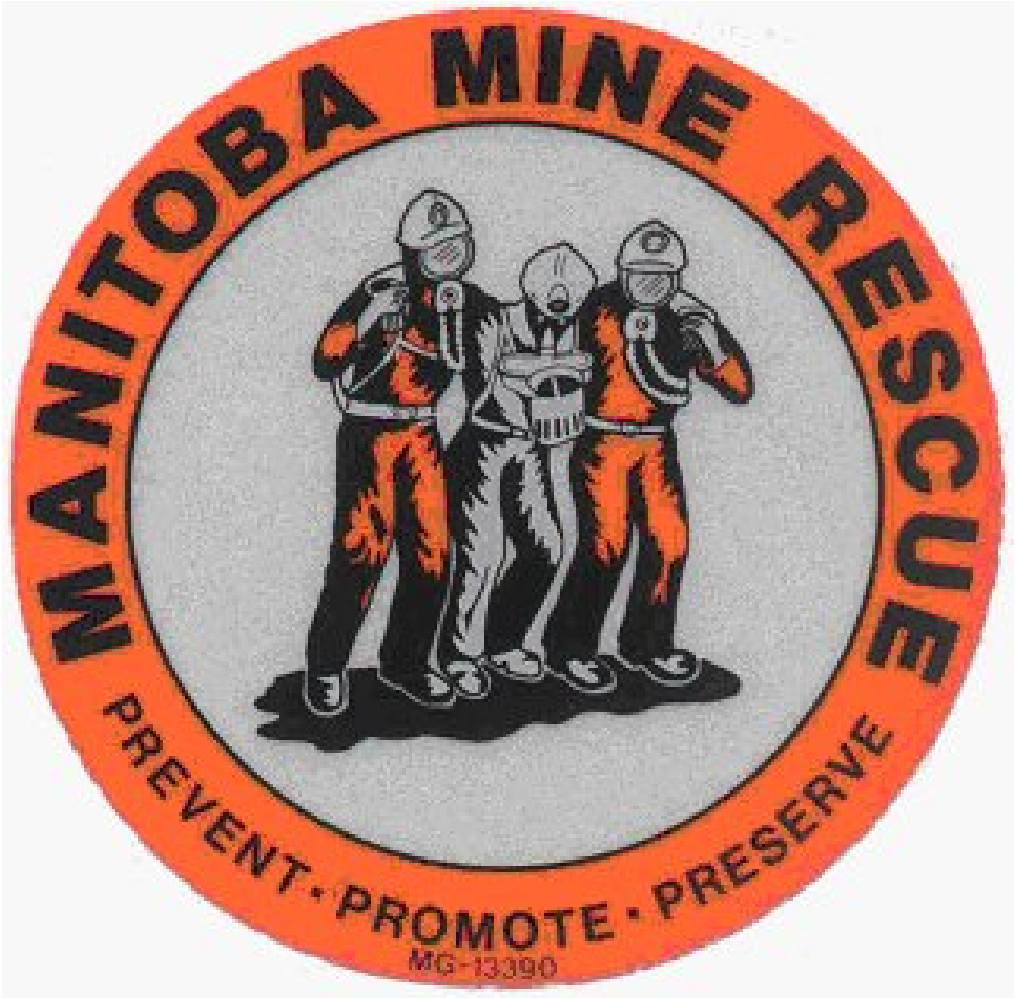

MANITOBA MINE RESCUE TRAINING & REFERENCE MANUAL

Acknowledgments

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American Conference of Industrial Hygienists Publication
Draeger Publications
IFSTA - Essentials Of Firefighting 4th Edition
Main Centre for Mine Rescue, Germany
Manual of Rescue Methods, USA
Mine Safety and Health Administration, USA
Mines Safety Appliance Company Publications
National Safety Council Publications
British Columbia Mine Rescue Manual
Ontario Mine Rescue Manual
Saskatchewan Mine Rescue Manual
Industrial Scientific Corporation

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LEARNING OBJECTIVES AND TARGET AUDIENCE

SECTION 1
INTRODUCTION

Learning Objectives

Section 1 is intended as general information only and does not need to be included in mine rescue training protocols.

Suggested Target Audience

Section Number	Topic	Basic Mine Rescue Trainees	Standard Mine Rescue Trainees	Advanced Mine Rescue Trainees	Mine Rescue Equipment Technicians	Mine Rescue Instructors	Director Of Operations & Resource Personnel	Senior Management Personnel	Supervisors	New Or Transferred Employees
1.1	What Is Mine Rescue?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
1.2	History Of Mine Rescue In Manitoba	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
1.3	Current Status Of Mine Rescue In Manitoba	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
1.4	Provincial Mine Rescue Competitions	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
1.5	Summary Of Competition Winners					**Yes**				
1.6	Summary Of Competition Runner ups					**Yes**				
1.7	Summary Of Technician Competition Winners					**Yes**				
1.8	Review Questions	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			

Section 1. Introduction

1.1 What Is Mine Rescue?

Mine rescue is a practical science whereby trained personnel, wearing protective breathing apparatus enter a mine during or after a mine fire, explosion, or other disaster to rescue trapped workers, extinguish the fire and restore the mine to its original safe condition.

Mine rescue training puts the mine operation in a state of "awareness." The mine is alerted to the possibility of an emergency occurring at any time.

This awareness encourages the mine personnel to utilize safe and proper working procedures that will often prevent emergency situations from occurring. The mine has a competent and knowledgeable work force able to take the proper action to prevent emergency situations from worsening and endangering lives. It is also equipped with specially trained personnel who can act during the emergency to carry out rescue and recovery operations.

Figure 1.1 – 1903 Draeger Smoke Protector

When a disaster occurs there are generally several factors contributing to the cause or to the severity, therefore, awareness has to be directed to the various causes.

Figure 1.2 – SCBA with no face piece - nose plugs and bite blocks used

1.2 History Of Mine Rescue In Manitoba

In 1933, Hudson Bay Mining and Smelting Company Limited, in Flin Flon, Manitoba, was the first mining company in Manitoba to have suitable mine rescue equipment and ten certified mine rescue personnel. For many years this was the only company to have, what can be referred to as a mine rescue station, although other mines had a limited supply of Type "N" gas masks. It was not until 1948 that HBM&S added to their equipment inventory, upgrading their station to the standard of a Central Mine Rescue Station. In the same year San Antonio Gold Mines Limited, at Bissett and Sherritt Gordon Mines Limited, at Sherridon established fully equipped stations. Howe Sound Exploration Company Ltd. in Snow Lake followed with a fully equipped station in 1949. The mine rescue station at Snow Lake was taken over by HBM&S after the gold mining operation of Britannia Mining and Smelting Co. Limited (formerly Howe Sound Exploration Company, Ltd.) was closed in 1958. In 1959 the equipment for the Thompson station was purchased by the International Nickel Company of Canada Limited (INCO). Beginning in 1967 the Draeger BG 174 - four hour CCBA replaced the McCaa, two hour self-contained breathing apparatus. As of the spring of 2007 all mine rescue stations in Manitoba have been equipped with the Draeger BG 4 Closed Circuit Breathing Apparatus.

Figure 1.3 – Type "N" Gas Mask

1.3 Current Status Of Mine Rescue In Manitoba

Mine rescue in Manitoba is defined in Manitoba by The Operation Of Mines Regulation 212/2011 5.4 (1), (2) & (3) and is the direct responsibility of each operating or developing mine. Mine rescue stations and sub-stations are currently maintained at six locations; Vale Manitoba Division, Thompson; Hudbay, Lalor / Chisel North Mine, Snow Lake; Hudbay, Flin Flon; Tanco, Lac Du Bonnet; San Gold Corporation, Bissett.

There were a number of other mine rescue stations throughout the Province in previous years until these mines ceased operations.

Annual evaluations are conducted on each mine rescue station to determine their level of compliance to the standards established for mine rescue and emergency preparedness in the Province of Manitoba.

Figure 1.4 – Chemox 1 Hour Oxygen Producing Unit

1.4 Provincial Mine Rescue Competitions

Annual mine rescue competitions are held in order to demonstrate the proficiency of emergency response personnel and the efficiency of the preparedness and response process.

The first Provincial Mine Rescue Competition in Manitoba was held in 1961. Judges travelled from station to station to evaluate the individual teams. In 1970, this format was changed, to have the teams travel to one location for the competition. Mine rescue competitions continue to be the focal point for skill testing and camaraderie. The winning team receives the trophy and members received an engraved flame lamp from MAPAM to commemorate the occasion. In 2009, the flame safety lamp was replaced with a limited edition statue, commissioned by MAPAM and created by artist Ernie Fauvelle.

Fig. 1.5 New Member Trophy

2006 was the first year all competing teams wore the BG 4 at the annual Manitoba Provincial Mine Rescue Competition.

In the 1992 competition Draeger Canada & National Mine Service donated a runner up trophy

for the teams competing. The members of the runner up team receive a plaque from Sling Choker as a memento of the competition.

1992 introduced the Technician Competition to the Provincials. This part of the competition was introduced to test the knowledge of the personnel who maintained and took care of the BG 174's. In 1997 National Mine Supply and Draeger donated a new trophy for the competition. The competition changed with the introduction of the BG 4's. The judges had to find a component common in all the stations and set the competition up for that component. With all teams now using the BG 4, the competition focuses on the technical part of the breathing apparatus and current equipment in use at all stations by the Mine Rescue Personnel. The technician most proficient during the competition receives the trophy and appropriate recognition.

1.5 Summary Of Competition Winners

1961	-	San Antonio Gold Mines, Bissett.
1962	-	San Antonio Gold Mines, Bissett.
1963	-	Hudson Bay Mining and Smelting, Flin Flon.
1964	-	Hudson Bay Mining and Smelting, Flin Flon.
1965	-	INCO, Thompson.
1966	-	Hudson Bay Mining and Smelting, Flin Flon.
1967	-	Sherritt Gordon Mines, Lynn Lake.
1968	-	Sherritt Gordon Mines, Lynn Lake.
1969	-	INCO, Thompson.
1970	-	Sherritt Gordon Mines, Lynn Lake.
1971	-	Tanco, Lac Du Bonnet.
1972	-	INCO, Thompson.
1973	-	Falconbridge, Man bridge.
1974	-	INCO, Thompson.
1975	-	Sherritt Gordon Mines, Lynn Lake.
1976	-	Hudson Bay Mining and Smelting, Flin Flon.
1977	-	Hudson Bay Mining and Smelting, Flin Flon.
1978	-	Hudson Bay Mining and Smelting, Snow Lake.
1979	-	Sherritt Gordon Mines, Leaf Rapids.
1980	-	Sherritt Gordon Mines, Leaf Rapids.
1981	-	Sherritt Gordon Mines, Lynn Lake.
1982	-	Hudson Bay Mining and Smelting, Snow Lake.
1983	-	INCO, Thompson.
1984	-	Sherritt Gordon Mines, Lynn Lake.
1985	-	Hudson Bay Mining and Smelting, Flin Flon.
1986	-	Atomic Energy of Canada Ltd. (URL) Pinawa.
1987	-	Hudson Bay Mining and Smelting, Flin Flon.
1988	-	Hudson Bay Mining and Smelting, Snow Lake.
1989	-	Lynn Gold, Lynn Lake.
1990	-	Hudson Bay Mining and Smelting, Leaf Rapids.
1991	-	INCO, Thompson.
1992	-	Tanco, Lac Du Bonnet.
1993	-	Hudson Bay Mining and Smelting, Flin Flon.
1994	-	Atomic Energy of Canada Ltd. (URL) Pinawa.
1995	-	Hudson Bay Mining and Smelting, Flin Flon.
1996	-	New Britannia Mine, Snow Lake.
1997	-	New Britannia Mine, Snow Lake.
1998	-	INCO, Thompson.
1999	-	Hudson Bay Mining and Smelting, Flin Flon.
2000	-	Tanco, Lac Du Bonnet.
2001	-	Hudson Bay Mining and Smelting, Leaf Rapids
2002	-	Atomic Energy of Canada Ltd. (URL) Pinawa.
2003	-	New Britannia Mine, Snow Lake.
2004	-	Atomic Energy of Canada Ltd. (URL) Pinawa.
2005	-	INCO, Thompson.
2006	-	Hudson Bay Mining and Smelting, Flin Flon.
2007	-	Hudson Bay Mining and Smelting, Snow Lake.
2008	-	Atomic Energy of Canada Ltd. (URL) Pinawa.
2009	-	Atomic Energy of Canada Ltd. (URL) Pinawa.
2010	-	Hudson Bay Mining and Smelting, Flin Flon.
2011	-	San Gold Corporation, Bissett
2012	-	Hudbay, Flin Flon

1.6 Summary Of Competition Runner Ups

1992	-	Hudson Bay Mining and Smelting, Flin Flon.
1993	-	Hudson Bay Mining and Smelting, Leaf Rapids
1994	-	Hudson Bay Mining and Smelting, Flin Flon.
1995	-	INCO, Thompson.
1996	-	INCO, Thompson.
1997	-	Atomic Energy of Canada Ltd. (URL) Pinawa.
1998	-	Hudson Bay Mining and Smelting, Snow Lake.
1999	-	New Britannia Mine, Snow Lake.
2000	-	Hudson Bay Mining and Smelting, Leaf Rapids
2001	-	Hudson Bay Mining and Smelting, Flin Flon.
2002	-	Hudson Bay Mining and Smelting, Leaf Rapids
2003	-	Atomic Energy of Canada Ltd. (URL) Pinawa.
2004	-	Hudson Bay Mining and Smelting, Flin Flon.
2005	-	Hudson Bay Mining and Smelting, Flin Flon.
2006	-	Atomic Energy of Canada Ltd. (URL) Pinawa.
2007	-	CVRD INCO Thompson
2008	-	Vale INCO Thompson
2009	-	Hudson Bay Mining and Smelting, Flin Flon.
2010	-	Atomic Energy of Canada Ltd. (URL) Pinawa.
2011	-	Vale Manitoba Division, Thompson
2012	-	San Gold Corporation, Bissett

1.7 Summary Of Technician Competition Winners

1992	-	Glen Snider	2003	-	Tony Butt
1993	-	Glen Snider	2004	-	Lorne Krul
1994	-	Dennis Wilson	2005	-	Tony Butt
1995	-	John Wedgwood	2006	-	Bryan Rainville
1996	-	Shawn Keith	2007	-	Garnet Coulson
1997	-	Robert Oleschak	2008	-	Kim Hayes
1998	-	Bob Southern	2009	-	Kim Hayes
1999	-	Len Bellin	2010	-	Kevin Clarke
2000	-	Kevin Clarke	2011	-	Carl Nilsson
2001	-	Dean Randell	2012	-	Kim Hayes
2002	-	Lorne Krul			

AECL /URL	
AECL/URL	
HBMS(FF)	
AECL/URL	
AECL/URL	
Inco	
New Britannia Mine	
Tanco	
AECL/URL	
AECL/URL	
New Britannia Mine	
HBMS (SL)	
New Britannia Mine	
HBMS (SL)	
HBMS (FF)	
HBMS (SL)	
Vale INCO	
Vale INCO	
AECL/URL	
Tanco	
Vale Manitoba Division	

Figure 1.6 – Mine Rescue Personnel Wearing The Chemox Breathing Apparatus

Figure 1.7 – Doing Checks On Man

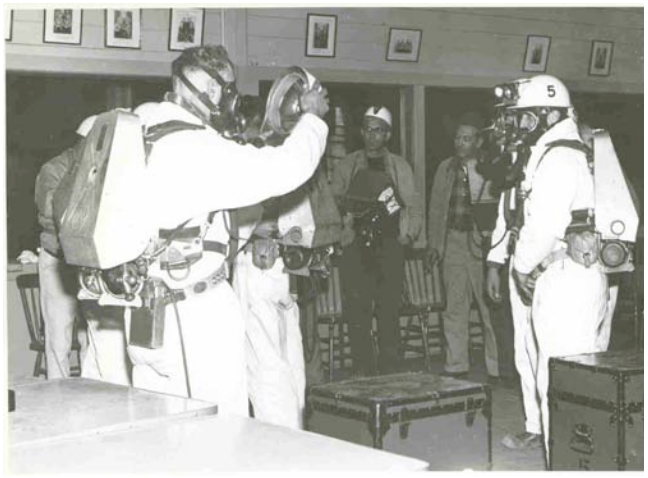

Figure 1.8 – Preparing to Go Into Mine

Figure 1.9 – Draeger U200 Oxygen Booster Pump

Figure 1.10 – INCO 1968

Figure 1.11 – Old Provincial Competition

Figure 1.12 – New Competition Trophy

Figure 1.13 - Runner Up Trophy For Provincial Competition

Figure 1.14 – Original Technician Trophy 1992 -96

Figure 1.15 – Technician Trophy 1997 - Present

U.S. Mine Rescue Team
Hollinger Fire
Whether by accident or spontaneous combustion – it was never determined – a fire started in an unused stope in the famous Hollinger Mine in an underground dump of wood dynamite boxes, wrappers and sawdust which wasn't supposed to be there. The miners, believing a fire couldn't burn in a hardrock mine, were slow to respond to their supervisors' cries of alarm. Without breathing apparatus and no means to fight the fire, management called on the U.S. Bureau of Mines Mine Rescue team which arrived at the mine in record time for the rail travel of the day. The Americans put out the fire and helped restore the mine ventilation but not before 39 men died underground. Shortly after, a Royal Commission recommended the establishment of the Ontario Mine Rescue system and, a year later, men were already being trained and equipped for the task.
The Porcupine Advance
Vol. XIII. No. 7
TIMMINS, ONTARIO, THURSDAY, FEBRUARY 16TH, 1928
Paid Circulation Last Week 2733
PRICE FIVE CENTS
DEATH TOLL 39 IN MINE ACCIDENT
Fire in Stope at Hollinger Causes Big Roll of Deaths
Mine Resumed Work This Morning
Judge Godson to Conduct Enquiry Into Disaster Here

Figure 1.16 – Mine Rescue Beginnings

Figure 1.17 – URL First Team To Win Provincial Competition Using The BG 4 – 2002.

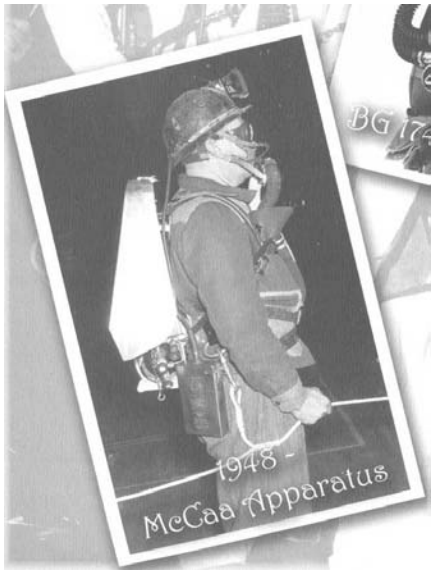

Figure 1.18 – The McCaa SCBA

OXYGEN-EQUIPPED CAGE USED FOR MINE-RESCUE BIRDS

Because the canary bird is easily overcome by the poisonous gases found in coal mines, one of them is carried into the workings by mine-rescue crews to indicate the presence of dangerous gas. The cage used for carrying the little bird is equipped with a glass door and an oxygen tank. When deadly gas is encountered and the canary is overcome by it, instead of being allowed to die, the door is closed and oxygen is administered until it revives.

This Cage, Used for Carrying Canaries Employed in Mine-Rescue Work, is Equipped with an Air-Tight Glass Door and Oxygen Tank

Figure 1.19 – Canary Cage

Figure 1.20 – Fire Fighting 1992 Provincial

Figure 1.21 – M^{c}Caa Breathing Apparatus At Station

1.8 Review Questions

1. Describe the importance of Mine Rescue in the Province of Manitoba.

2. In your own words, describe “mine rescue”.

3. What Manitoba company was the first to have a mine rescue station and in what year?

4. Why are annual mine rescue competitions held in the Province of Manitoba?

5. What was the date of the newspaper article that stated “Death Toll 39 in Mine Accident”?

LEARNING OBJECTIVES AND TARGET AUDIENCE

SECTION 2
MINE RESCUE TRAINING & RECOGNITION

Learning Objectives

Section 2 is intended as general information only and does not need to be included in mine rescue training protocols.

Suggested Target Audience

Section Number	Topic	Basic Mine Rescue Trainees	Standard Mine Rescue Trainees	Advanced Mine Rescue Trainees	Mine Rescue Equipment Technicians	Mine Rescue Instructors	Director of Operations & Resource Personnel	Senior Management Personnel	Supervisors	New Or Transferred Employees
2.1	General Requirements For Mine Rescue					**Yes**	**Yes**	**Yes**		
2.2	Basic Mine Rescue Training	**Yes**				**Yes**				
2.3	Recommended Course Outline For Basic Mine Rescue Training	**Yes**				**Yes**				
2.4	Standard Mine Rescue Training		**Yes**	**Yes**	**Yes**	**Yes**				
2.5	Recommended Course Outline For Standard Mine Rescue Training		**Yes**	**Yes**	**Yes**	**Yes**				
2.6	Advanced Mine Rescue Training			**Yes**	**Yes**	**Yes**				

2.7	Criteria For Mine Rescue Instructor Certification In Manitoba			**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
2.8	Criteria For Independent Mine Rescue Instructor Certification In Manitoba			**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
2.9	Director Of Operations Training			**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
2.10	Seals Of Recognition	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
2.11	Long Term Service Awards	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
2.12	Review Questions	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		

Section 2. Mine Rescue Training and Recognition

2.1 General Requirements For Mine Rescue

Criteria for the qualification, selection and certification of emergency response personnel (mine rescue personnel) is contained in a document titled: **"Manitoba Mine Rescue Organization Station Manual".**

Criteria for Emergency Response Personnel:

- Minimum age of 18 as per Manitoba Regulation 212/2011; The Operation of Mines Regulation – Part 2.7.
- Organically sound, in good health, physically fit and mentally suitable.
- Physically and mentally able to endure long and arduous tasks.
- Of good character and habit and exercises good judgment.
- Rational, reasonable and able to remain calm & collected during crisis.
- Able to wear a respirator unencumbered by facial or cranial hair or abnormalities of the face or head.
- Not wear make up or jewellery (e.g. rings, body jewellery), which could encumber the use of a respirator or put a person at risk of injury.
- Adequate vision and hearing (as specified).
- Knowledgeable about the underground environment and mine related activities.
- Hold a valid First Aider 2 - St. John Ambulance, Red Cross or equivalent first aid certificate and maintain a minimum level of two person CPR, be trained in spinal immobilization and oxygen therapy / administration.
- Able to communicate in the dominant language of the mine (eg: English).

Mine rescue personnel and other persons assigned to wear a SCBA (self contained breathing apparatus) shall have a pre-placement (baseline) medical examination. The attending medical doctor will be required to determine whether the person is considered "fit" or "unfit" for mine rescue activities.

Every second year or as may be required or requested (change in health status, post serious hazard exposure), each mine rescue person must submit to a medical examination by a medical doctor. Medical examinations may utilize some or all of the baseline examination criteria.

2.2 Basic Mine Rescue Training

Basic mine rescue certification is considered to be entry level mine rescue training. The Basic Mine Rescue Course is taught by qualified mine rescue instructors in the Province of Manitoba.

Potential mine rescue candidates must meet the “Criteria for Emergency Response Personnel”. This is to be done prior to participating in aspects of the mine rescue training where they are required to perform demanding work while wearing oxygen breathing apparatus.

Basic mine rescue training shall be a minimum of 24 hours (more as required) and must allow participants ample time to become familiar with the course materials and equipment. Instructors will use their discretion to determine if additional time is required to successfully complete the training course.

In order to qualify for certification, the participant must demonstrate a satisfactory degree of knowledge, skill, competency and proficiency in the use of mine rescue equipment and must attain a minimum of 80% on a final exam.

Upon successful completion of training, participants are presented with a Basic Mine Rescue Certificate, issued by the Mines Accident Prevention Association of Manitoba (MAPAM), endorsed by the instructor and approved by the Director, Mine Safety Branch. In addition, they receive a hat decal and lapel pin.

2.3 Recommended Course Outline For Basic Mine Rescue Training

Suggested Course Outline - Basic Training

COURSE DAY 1

Registration & Paperwork ..... 30 minutes
Lectures and Demonstrations
- Objects of Mine Rescue and Recovery Work ..... 15 minutes
- Overview of the Emergency Response Structure ..... 10 minutes
- Team Work Discipline, Signals and procedures ..... 45 minutes
- Air, Mine Air and Contaminants ..... 30 minutes
- Toxic Gases in Mine Air ..... 60 minutes
- Treatment for Gas Poisoning ..... 30 minutes
- Introduction to Gas Detection Instruments ..... 60 minutes
- Methods of Protection Against Gases ..... 20 minutes
- Types of Protective Equipment ..... 30 minutes
- Introduction to O_2 Self Contained Breathing Apparatus ..... 30 minutes
- Testing and Wearing O_2 SCBA in Good Air ..... 60 minutes

Total ..... 420 Minutes (7 Hours)

COURSE DAY 2

- Toxic Gases recap ..... 60 minutes
- O_2 SCBA Testing and Wearing in Good Air ..... 120 minutes
- O_2 SCBA Cleaning and Maintenance ..... 90 minutes
- Self Rescuers and Auxiliary Breathing Apparatus and Equipment Specific to the Minesite ..... 150 minutes

Total ..... 420 Minutes (7 Hours)

COURSE DAY 3

Recap Breathing Protection ..... 60 minutes
Test and Wear O_2 SCBA in Smoke ..... 120 minutes
O_2 SCBA Cleaning and Maintenance ..... 120 minutes
Auxiliary Mine Rescue Equipment ..... 120 minutes

Total ..... 420 Minutes (7 Hours)

COURSE DAY 4

Candidates Demonstrate Field Test on O_2 SCBA ..... 60 minutes
Final Exam ..... 120 minutes

Total ..... 180 Minutes (3 Hours)

2.4 Standard Mine Rescue Training

Mine rescue personnel who have a valid, Basic mine rescue certificate, may, after at least 12 months of active mine rescue experience, be considered for Standard mine rescue training. Standard mine rescue accreditation is administered by qualified mine rescue instructors in the Province of Manitoba. The mine rescue instructor will select and certify participants in accordance with Manitoba mine rescue criteria.

In order to achieve Standard mine rescue certification, the candidate must:

- Be familiar with gas detection equipment.
- Possess knowledge of TLV's, STEL & IDLH.
- Be familiar with the procedures to conduct a station test on the primary breathing apparatus.
- Be able to work in a team format.
- Demonstrate an ability to travel and work in smoke.
- Be able to perform demanding work while under oxygen (eg: construct seals or build barricades).
- Be able to pump oxygen and use a cascade system.
- Know how to use oxygen therapy equipment.

- Achieve 80% on a final exam.
- Meet other criteria as may be defined by the mine rescue instructor or Manitoba Mine Rescue Instructor Organization.

Note: The time frames set out below show a general course outline and may differ somewhat in the training offered. It will be up to the Mine Rescue Instructor to ensure candidates receive appropriate and adequate training before granting certification.

Once the candidate has met the criteria, they will be issued a Standard mine rescue seal for application to the mine rescue certificate.

2.5 Recommended Course Outline For Standard Mine Rescue Training

COURSE DAY 1

Enrollment, Explanation and
Clarification on Standard Training ..... 60 minutes
Field testing and wearing O_2 SCBA practice
team travel in clear air and light smoke ..... 120 minutes
Cleaning and basic maintenance O_2 SCBA* ..... 60 minutes
Station Test O_2 SCBA* ..... 60 minutes
Compressed air apparatus, use and service* ..... 60 minutes
Self Rescuers* ..... 60 minutes

Total ..... 420 Minutes (7 Hours)

(* indicates as appropriate)

COURSE DAY 2

Service, field test and wear O_2 SCBA in smoke,
construct barricade with lumber and suitable cover ..... 180 minutes
Station Test O_2 SCBA* ..... 30 minutes
Filter Type Apparatus Use and Service ..... 60 minutes
Oxygen Resuscitation Equipment* ..... 60 minutes
Oxygen Transfer Pumps and Cascade Systems* ..... 60 minutes
Mine Gases - TLV's, STEL & IDLH ..... 60 minutes

Total ..... 450 Minutes (7.5 Hours)

(* indicates as appropriate)

COURSE DAY 3

Service, field test and wear O_2 SCBA in smoke, construct
sand bag barricade ..... 180 minutes
Perform arduous work ..... 120 minutes
Final Exam ..... 120 minutes

Total ..... 420 Minutes (7 Hours)

2.6 Advanced Mine Rescue Training

Mine rescue personnel who have a valid Standard mine rescue certificate may, after three years of active mine rescue experience, be considered for Advanced mine rescue certification. Advanced mine rescue accreditation is administered by qualified mine rescue instructors in the Province of Manitoba. The mine rescue instructor will select and certify participants in accordance with Manitoba mine rescue criteria.

Competency at the Advanced level of mine rescue certification includes but is not limited to:

- Use, care and maintenance of specialty equipment.
- Understand mine rescue as it relates to the companies emergency preparedness and response program.
- Ability to manage a mine rescue mission.
- Must possess a valid first aid certificate (first aider 2 minimum from a recognized organization) with a minimum level of two person CPR, be trained in spinal immobilization and oxygen therapy / administration.
- Other criteria as may be defined by the mine rescue instructor or Manitoba Mine Rescue Organization.

Specific time frames have not been identified to complete this certification process however it will be up to the Mine Rescue Instructor to ensure candidates receive appropriate and adequate training before granting certification.

2.7 Criteria For Mine Rescue Instructor Certification In Manitoba

The following certification for Mine Rescue Instructor Certification was adopted on March 18, 1998.

- The prospective mine rescue instructor candidate will be selected by the mining company to fulfil a role as mine rescue co-ordinator, trainer, facilitator or instructor.
- The prospective mine rescue instructor candidate must hold an Advanced Mine Rescue Certificate in the Province of Manitoba.
- The prospective mine rescue instructor candidate must be certified as a Technician for oxygen breathing apparatus as per manufacturer guidelines.
- The prospective mine rescue instructor candidate must demonstrate an ability to teach adults. This assessment may be determined by a company representative or by a qualified mine rescue instructor.
- The prospective mine rescue instructor candidate must have successfully taught a Basic or Standard Mine Rescue Training Course under the direction of a qualified instructor and / or must have been employed as a mine rescue instructor where mine rescue personnel are trained and managed by that person for a period of at least one year.
- The prospective mine rescue instructor candidate's company, when appropriate, will forward to MAPAM a letter of recommendation indicating the company is satisfied with the candidates capability to fulfil a role as a mine rescue instructor and they meet the eligibility requirements for certification.
- MAPAM will prepare a certificate for signature by a qualified mine rescue instructor, MAPAM Director of Risk Management and / or the Director, Mine Safety Branch.

2.8 Criteria For Independent Mine Rescue Instructor Certification In Manitoba

The following certification for Independent Mine Rescue Instructor Certification was adopted by the Mine Rescue Instructors Association in November 2011.

- The prospective independent mine rescue instructor candidate must hold an Advanced Mine Rescue Certificate in the Province of Manitoba.
- The prospective independent mine rescue instructor candidate must have held a Mine Rescue Instructor Certification with a mining company in the Province of Manitoba to fulfill a role as mine rescue co-ordinator, trainer, facilitator or instructor.
- The independent mine rescue instructor or candidate must be certified as a Technician for oxygen breathing apparatus as per manufacturer guidelines.
- The independent mine rescue instructor or candidate must demonstrate an ability to teach adults. This assessment may be determined by a company representative or by a qualified mine rescue instructor and MAPAM.
- The independent mine rescue instructor candidate must have successfully taught a Basic Mine Rescue Training Course under the direction of a qualified instructor and / or must have been employed in Canada at an underground facility as a mine rescue instructor where mine rescue personnel are trained and managed by that person for a period of at least one year.
- The prospective independent mine rescue instructor candidate, when appropriate, will forward to MAPAM, all training documents, a letter of recommendation indicating the company is satisfied with the candidate's capability to fulfill a role as an independent mine rescue instructor and they meet the eligibility requirements for certification.
- MAPAM will prepare a certificate for signature by a qualified mine rescue instructor, MAPAM Director of Risk Management and / or the Director, Mine Safety Branch.
- To maintain the independent mine rescue instructor certification the instructor must:
    - Attend one Mine Rescue Instructors meeting per year.
    - Lead or assist in a Basic Mine Rescue Training Course
    - Judge a Provincial Competition once every two years.

2.9 Director Of Operations Training

The Director of Operations (Director or D.O.**)** is a key person during a mine emergency. Depending on the circumstances, the Director may interact only with the mine rescue team during an emergency or in a more serious situation, provide the liaison link between the team and the emergency control centre. The Director of Operation's primary function is to maintain contact with the mine rescue team in order to gather information from the team, provide information and direction to them and maintain a detailed record of activities associated with the mine emergency. Directors must be familiar with mine operations and have a basic understanding of mine rescue principles and the procedures directing the activities of emergency response personnel. The Mine Rescue Instructors may wish to include information specific to the mine site they are working at.

The training may contain but is not limited to the following:

- Establishing of a control centre and briefing room (surface) and planning for a fresh air base for underground.
- Organizing and delegating of tasks to various knowledgeable personnel whose expertise may be required during emergency.
- Collecting of all available data pertaining to the emergency.
- Developing a plan for the emergency response including a rotation schedule for the rescue personnel.
- Briefing of the mine rescue teams.
- Communicating with the mine rescue team as they explore the mine.
- Using the corporate emergency procedures.
- Ensuring the security of the mine site.
- Ensuring gas monitoring and ventilation readings are continued.
- Maintaining communication with the Mine Rescue Co-ordinator(s) to make sure there is required and auxiliary equipment available for rescue personnel on site and reserve, monitor status of reserves and status of personnel having returned from the emergency.
- Maintaining the necessary documentation required for use during an emergency.
- Ensuring procedures and protocols used by Mine Rescue are being maintained.

The Director may be delegated to take control of non-emergency missions for Mine Rescue. This could include: assessing old workings and ventilation check, starting a fan in bad air / re-hanging vent tubing, underground practice, live fire training or rope rescue practice. The Director must at all times continue to follow established protocols and procedures as developed for Mine Rescue even though it is a non-emergency mission.

Each year, MAPAM tests the proficiency of our emergency preparation and response capability through annual competitions. The competency of the Director of Operations is also demonstrated at this time.

2.10 Seals Of Recognition

2.10.1 Active Seal

Mine rescue personnel who are considered "Active" are issued a seal indicating the year of active duty. In order to qualify for “Active” status, mine rescue personnel must meet medical criteria and have participated in at least 40 hours of routine training during the previous year. These seals should be affixed to their mine rescue certificate.

2.10.2 Emergency Response Seal

When mine rescue personnel actively participate during an emergency response situation they are issued a seal indicating date, location and nature of the emergency. These seals should be affixed to their mine rescue certificate.

2.10.3 Competition Winner Seal

The winners of the annual Provincial Mine Rescue Competition are issued appropriate recognition seals which are affixed to their mine rescue certificate.

2.11 Long-Term Service Awards

The Manitoba Mine Rescue Organization will present to those members fulfilling the criteria listed below long-term service awards in increments of five years.

It was determined long service awards may be given to people who have been directly involved in mine rescue activities over an extended period of time. If they meet the following criteria:

(1) They must have been previously certified to at least basic mine rescue level.

(2) They work in the capacity of reserve status, coach, trainer, Director of Operations or other capacity directly related to mine rescue.

The following definitions will determine the status of a Mine Rescue Member:

"Active", - requires mine rescue personnel to meet medical criteria and have participated in at least 40 hours of routine training during the previous year.

"Reserve Mine Rescue Personnel" - will be required to participate in a minimum of eight hours of mine rescue training annually, of which a minimum of two hours must be under oxygen.

2.12 Review Questions

1) List five criteria for Emergency Response Personnel in the Province of Manitoba.

2) List three requirements necessary to obtain Basic Mine Rescue Certification in the Province of Manitoba.

3) List nine requirements to achieve Standard Mine Rescue Certification in the Province of Manitoba.

4) List five duties of the Director of Operations.

LEARNING OBJECTIVES AND TARGET AUDIENCE

SECTION 3
ORGANIZATION FOR MINE RESCUE WORK

Learning Objectives

Section 3 provides an overview of the emergency response organization with particular focus on the administrative structure and management of an emergency.

Suggested Target Audience

Section Number	Topic	Basic Mine Rescue Trainees	Standard Mine Rescue Trainees	Advanced Mine Rescue Trainees	Mine Rescue Equipment Technicians	Mine Rescue Instructors	Director of Operations & Resource Personnel	Senior Management Personnel	Supervisors	New Or Transferred Employees
3.1	Purpose Of Mine Rescue	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
3.2	Sequence Of Events During A Mine Emergency	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
3.3	Emergency Control Centre			**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
3.4	Structure Of Mine Rescue Teams			**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
3.5	Fresh Air Base			**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
3.6	Requirements For Mine Rescue Teams During Extended Emergencies			**Yes**		**Yes**	**Yes**	**Yes**		
3.7	Rest Facilities And Feeding					**Yes**	**Yes**	**Yes**		
3.8	Sample Rotation Schedules For Active, Back-up And Reserve Teams					**Yes**	**Yes**	**Yes**		
3.9	Mutual Aid For Mine Rescue In Manitoba	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
3.10	Review Questions	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		

Section 3. Organization For Mine Rescue Work

3.1 Purpose Of Mine Rescue

The three main **objectives** of mine rescue and recovery work are:

(1) Locate and rescue underground personnel that may be at risk.

(2) Locate and extinguish incipient or active fires or deal with other emergencies.

(3) Rehabilitate the mine as required.

With these objectives in mind, a mine rescue team must be constantly aware of conditions in the mine environment, status of breathing apparatus, the availability of equipment and must take all precautions to ensure their personal safety at all times.

3.2 Sequence of Events During A Mine Emergency

When a mine emergency is identified:

- Primary response should be taken by person(s) identifying the emergency.
- Emergency response plan must be initiated.
- Appropriate people must be contacted (Mine personnel, mutual assistance, mines inspector etc.).
- Emergency Control Centre should assume control.
- Response plan should be initiated.
- Action should be taken to manage the emergency.

3.3 Emergency Control Centre

The emergency control centre is where policy and plans of procedure are decided upon. The Mine Manager or designate would be the head of this group, and all applicable support staff would be available for consultation. For example, mine engineering would assist with providing updated mine plans and ventilation, the electrical department would have knowledge about power distribution and warehousing could assist with acquisition of goods and materials.

All information should be passed on to rescue teams, or other persons involved, through the Director of Operations. The Director of Operations is an integral part of mine rescue training and emergency preparedness and response. They must act as

the link between mine rescue teams underground and surface. Although the Director of Operations is not required to be mine rescue certified, it is important they have a basic understanding of the structure and purpose of mine rescue and the procedures teams follow when involved in a mine rescue mission. Reports from teams should be made directly to the Director of Operations or person authorized by the Director.

3.4 Structure Of Mine Rescue Teams

A typical mine rescue operation where response personnel are required to wear breathing apparatus, must consist of fifteen people; five on the primary response team, an additional five to provide back-up assistance should the need arise and five more in reserve status to provide support to the second team in the event that team is deployed to assist the primary response team.

Only in an extreme emergency, when lives are at stake and conditions are carefully weighed, may three or four persons act as a team, but never without a back-up team. Sufficient time must be given, to allow mine rescue personnel to test and prepare their apparatus. Teams must be briefed with as much detail as possible and if necessary in writing. Two way communications is imperative to ensure all information and instructions are clearly understood by all parties.

The back-up and reserve team (when possible), should also be included in the briefing in order to understand the nature of the emergency and understand the direction given to the primary response team.

3.5 Fresh Air Base

The fresh air base is the location where all or a portion of mine rescue activities are co-ordinated from.

The essentials of a fresh air base include the following:

(a) An assured supply of fresh air.

(b) Communication with headquarters on surface by telephone or radio.

(c) The best illumination possible.

(d) Sufficient room to permit efficient work without confusion.

Appropriate support personnel should be stationed at the fresh air base in order to direct the emergency response work and maintain operations.

The fresh air base should be equipped with tables, benches for the back-up and reserve teams, tables for overhauling rescue apparatus, tools and repair parts for maintaining apparatus and the necessary tools and supplies for conducting the required work. If there is more than one fresh air base, it may be necessary to set up a general headquarters. The base may be on surface or underground, as conditions dictate and should be as near the emergency scene as practical.

A team should not be sent ahead of an established fresh air base unless there is a fully equipped back-up team available and a reserve team readily available.

3.6 Requirements For Mine Rescue Teams During Extended Emergencies

Mine Rescue work can be demanding and strenuous. During extended emergency response activities, medical staff should be available to monitor the physical and mental well being of emergency responders. If there is an indication of a medical problem, a more detailed examination may be required. Persons responsible for the overall management of an emergency response situation must be keenly aware of the need to monitor the physical and mental health of emergency responders and take appropriate action as necessary

3.7 Rest Facilities And Feeding

Mine rescue response personnel must be adequately rested during an emergency response exercise and must be given foods, which are nutritional and not high in fat or sugar. During a long response operation it may be advisable to engage the services of a dietician to ensure proper foods are being consumed.

In order to ensure members of rescue teams keep physically fit during mine and recovery operations, the following arrangements must be made and adhered to:

(a) No member should remain longer than six hours on one shift. During this period, rescue personnel should not be permitted to remain under oxygen longer than two hours, unless it becomes necessary to search for an overdue team or excessive travelling time is involved.

(b) It is recommended rescue personnel not be permitted to undertake a second shift until after they have had at least six hours rest.

In the event a three team rotation is being used during an emergency, it may be necessary to make a rotation of the three teams. This is acceptable only if the command centre realizes the emergency is limited

and is going to be completed with the three teams only being required. If this is not the case the Director and Mine Rescue Co-ordinator must call out more teams to give those teams already on the emergency a proper rest cycle as stated above.

(c) Rescue personnel should not be permitted to take a second shift in contaminated air without having been examined and found fit by a competent person.

(d) Shower and washroom facilities should be available for rescue and support personnel.

(e) Nutritional, well-prepared food, not too rich in sugar and fats, should be eaten in moderation. No food should be eaten for one hour before taking active part in rescue and recovery work.

(f) Where necessary, clean, quiet sleeping or rest facilities should be available for rescue and support personnel.

3.8 SAMPLE ROTATION SCHEDULES FOR ACTIVE, BACK-UP AND RESERVE TEAMS

3 Team Arrangements
(8 - Hour Period)

Team No.	Description	2 hrs.	2 hrs.	2 hrs.	2 hrs.							
1.		Active	Reserve	Back-up at F.A.B.	Active							
2.		Back-up at F.A.B.	Active	Reserve	Back-up at F.A.B.							
3.		Reserve	Back-up at F.A.B.	Active	Reserve							

Four Team Arrangements
(12 - Hour Period)

Team No.	Description	2 hrs.	2 hrs.	2 hrs.	2 hrs.	2 hrs.	2 hrs.					
1.		Active		Reserve	Back-up at F.A.B.	Active						
2.		Back-up at F.A.B.	Active		Reserve	Back-up at F.A.B.	Active					
3.		Reserve	Back-up at F.A.B.	Active		Reserve	Back-up at F.A.B.					
4.			Reserve	Back-up at F.A.B.	Active		Reserve					

Five Team Arrangements
(12 - Hour Period)

Team No.	Description	2 hrs.	2 hrs.	2 hrs.	2 hrs.	2 hrs.	2 hrs.					
1.		Active			Reserve	Back-up at F.A.B.	Active					
2.		Back-up at F.A.B.	Active			Reserve	Back-up at F.A.B.					
3.		Reserve	Back-up at F.A.B.	Active			Reserve					
4.			Reserve	Back-up at F.A.B.	Active							
5.				Reserve	Back-up at F.A.B.	Active						

Six Team Arrangements
(24 - Hour Period)

Team No.	Description	2 hrs.	2 hrs.	2 hrs	2 hrs	2 hrs	2 hrs	2 hrs	2 hrs	2 hrs	2 hrs	2 hrs	2 hrs
1.		Active				Reserve	Back-up at F.A.B.	Active				Reserve	Back-up at F.A.B.
2.		Back-up at F.A.B.	Active				Reserve	Back-up at F.A.B.	Active				Reserve
3.		Reserve	Back-up at F.A.B.	Active				Reserve	Back-up at F.A.B.	Active			
4.			Reserve	Back-up at F.A.B.	Active				Reserve	Back-up at F.A.B.	Active		
5.				Reserve	Back-up at F.A.B.	Active				Reserve	Back-up at F.A.B.	Active	
6.					Reserve	Back-up at F.A.B.	Active				Reserve	Back-up at F.A.B.	Active

This arrangement is made up to a maximum force of six teams, and allows for six hours on duty and six hours complete rest. As more teams become available, and if the emergency indicates an extensive operation, a nine team arrangement is advisable, whereby the team members would have a twelve hour rest period.

Nine Team Arrangements
(24 - Hour Period)

Team No.	Description	2 hrs.	2 hrs.	2 hrs	2 hrs	2 hrs	2 hrs	2 hrs	2 hrs	2 hrs	2 hrs	2 hrs	2 hrs
1.		Active							Reserve	Back-up at F.A.B.	Active		
2.		Back-up at F.A.B.	Active							Reserve	Back-up at F.A.B.	Active	
3.		Reserve	Back-up at F.A.B.	Active							Reserve	Back-up at F.A.B.	Active
4.			Reserve	Back-up at F.A.B.	Active							Reserve	Back-up at F.A.B.
5.				Reserve	Back-up at F.A.B.	Active							
6.					Reserve	Back-up at F.A.B.	Active						
7.						Reserve	Back-up at F.A.B.	Active					
8.							Reserve	Back-up at F.A.B.	Active				
9.								Reserve	Back-up at F.A.B.	Active			

This arrangement is made up for a maximum of twelve teams and allows for six hours on duty and twelve hours complete rest.

3.9 Mutual Aid Assistance for Emergency Response in Manitoba

San Gold Corporation
Emergency Numbers
(204) 277-5411
Security – Ext. 217
Hoistroom – Ext. 201

TANCO
Administration or Security
Emergency Response Number
(204) 884-2400
Dial 0

Hudbay - Flin Flon
Main Gate
Emergency Number
(204) 687-2291

VALE Manitoba Division
Surface First Aid
Emergency Number
(204) 778-2276

Hudbay - Snow Lake
Main Gate in Flin Flon
Emergency Number
(204) 687-2291

Barrie Simoneau – MAPAM
Director of Risk Management
Mines Accident Prevention Association of Manitoba (MAPAM)
Office (204) 989-1890 Cell (204) 299-9409 - Home (204) 254-4724

The Canadian mining industry has traditionally been a very close-knit community, dealing with issues of common interest in a collaborative and unified manner. This cooperative approach has developed due to the uniqueness of the industry, the location of mines and the expertise necessary to respond to mining related issues.

One common interest area is emergency preparedness and response planning at mine sites. The majority of operating mines have developed and tested, comprehensive emergency plans for accident prevention, emergency preparedness, disaster response and business resumption activities. In most plans there is an element of mutual assistance that links operating mines with Federal, Provincial and Municipal agencies and in some cases with minesites within the province or in a neighbouring province.

Mining companies are generally very capable of dealing with emergencies on their own, however there are occasions when the nature, or duration of the emergency requires the assistance of a third party. Historically, other mines have always been

quick to respond to a call for emergency assistance. These calls for help have been structured around the terms of “mutual aid agreements”, which state;

> The Mutual Aid Assistance Matrix confirms operating mines in Manitoba support the principles of mutual assistance as contained in the Mutual Aid Agreement & Emergency Response Services document (November 2011) and agree to provide assistance to other parties of this agreement wherever and whenever it is reasonable and practical to do so.

During a mine emergency, it may be necessary to seek mutual assistance from a neighbouring mine or province. Should this situation arise, it is imperative the operating mines identified in the Mutual Aid Assistance & Emergency Response Matrix be alerted as quickly as possible. Once alerted, a mutual assistance neighbour should take the necessary action to prepare to respond to the emergency, if requested. The nature of the emergency will determine how many mutual assistance neighbours should be contacted.

3.10 Review Questions

1) What are the main objectives of Mine Rescue and Recovery Work?

2) In case of a mine fire, explosion or other disaster, who should be notified?

3) What other measures should be taken during the notification phase of a mine emergency?

4) During an emergency, the Mine Manager or designate is in charge of the emergency control center. Who should give instructions to the mine rescue teams? Why?

5) How many active mine rescue personnel are required before a five person team can be sent on an emergency response mission?

6) What are the requirements of a fresh air base?

7) What is the primary consideration in establishing a fresh air base underground?

8) What is the maximum amount of time a mine rescue team member should be on one shift?

9) What should occur before a mine rescue team member undertakes a second shift in contaminated air?

10) What types of food should be made available to mine rescue team members during a mine emergency? \

11) After eating, what period of time should elapse before a mine rescue member is allowed to wear self contained breathing apparatus?

12) What is the recommended amount of rest time after mine rescue team members have been under oxygen?

13) Explain the purpose of the Mutual Aid Assistance & Emergency Response Matrix.

LEARNING OBJECTIVES AND TARGET AUDIENCE

SECTION 4
VENTILATION

Learning Objectives

Section 4 provides a basic overview of mine ventilation systems, and briefly explains how to measure and control throughout the mine environment.

Suggested Target Audience

Section Number	Topic	Basic Mine Rescue Trainees	Standard Mine Rescue Trainees	Advanced Mine Rescue Trainees	Mine Rescue Equipment Technicians	Mine Rescue Instructors	Director Of Operations & Resource Personnel	Senior Management Personnel	Supervisors	New Or Transferred Employees
4.1	Mine Ventilation	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
4.2	Methods Of Ventilating	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
4.3	Assessing Ventilation	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
4.4	Ventilation Controls	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
4.5	Building Ventilation Controls		**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
4.6	Review Questions	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Section 4. Ventilation

4.1 Mine Ventilation

In order to resolve a mine rescue emergency, it may be necessary to deal with the mine ventilation system, therefore a basic understanding of mine ventilation is necessary for emergency response personnel.

No two mines have exactly the same ventilation system, therefore this section will only cover general ventilation for underground mines. For the purposes of training and emergency response, current ventilation plans must be readily available to mine rescue personnel.

Ventilation Systems Serve Two Basic Functions:

1. Provide a continuous flow of breathing air to mine workings.
2. Remove, air containing contaminants from the mine workings via an exhaust system.

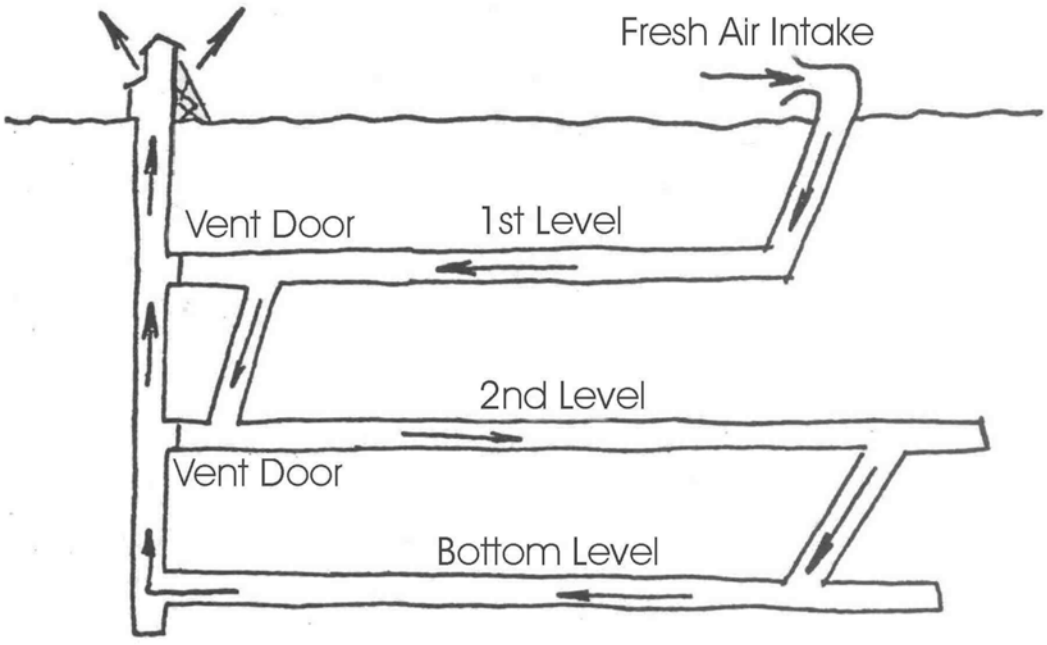

Figure 4.1 – Basic mine ventilation system.

4.2 Methods Of Ventilating:

There are THREE methods of providing ventilation:

1. **Natural Ventilation** (convection) – Airflow due to the differences in temperature and pressure.

2. **Primary Ventilation** – Air is moved in and out of the mine using electric fans, often in conjunction with a heating or cooling system.

3. **Secondary Ventilation** – Electric or air fans situated underground redistribute mine air to wherever it is required throughout the mine. Auxiliary ventilation may be used to ventilate dead end drifts, raises, shops and lunchrooms or any other location where breathing air is required.

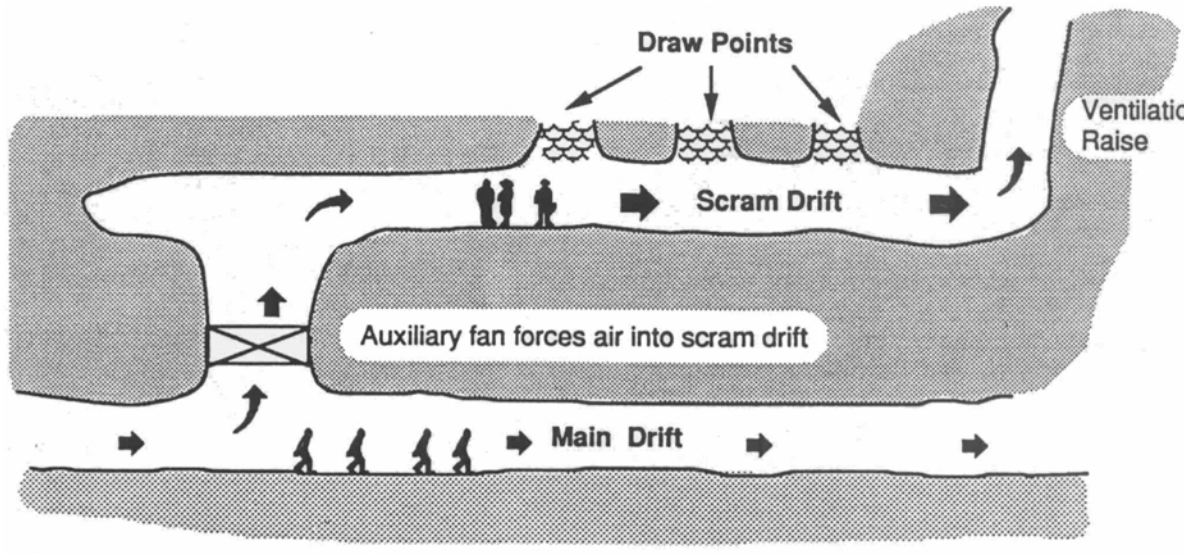

Figure 4.2 – Sample of supplying ventilation by just using a fan to direct air flow.

4.3 Assessing Ventilation

During a mine emergency, it is very important to determine as quickly as possible what the condition of the ventilation system is. This includes knowing the condition of the ventilation controls and the direction and velocity of the airflow throughout the underground mine.

There are times when a mine rescue team will be required to determine the direction

and volume of airflow in a specific section of the mine. Their ability to calculate airflow will help to determine if the ventilation system is functioning as it should. Air flow may be determined using a velometer, anemometer or by utilizing a measuring tape and smoke tube.

As emergency response personnel advance into the mine during an emergency, they should check the condition of ventilation control systems, especially those in areas affected by the emergency. When a mine rescue team encounters a regulator or door, their condition and open / closed position should be noted on the map and reported to the Director of Operations.

Figure 4.3 - Velometer

The team should check the condition of the auxiliary fans, ventilation tubing and compressed air lines. The positions of the valves (open or closed) should be noted and reported to Director of Operations. If a compressed air line is damaged, trapped or missing personnel who may be depending on that air supply may be placed at higher risk. In addition, air powered equipment such as fans and high expansion foam generators will not function.

Personnel in the command center and more importantly, the Director of Operations, must receive accurate information from the team regarding the ventilation controls, air lines bulkheads, doors etc. This information may be important if changes to ventilation or physical conditions in the mine are necessary. **No changes** are to be made to mine ventilation.

NOTE: In a confined area such as the underground environment, fires tend to create their own ventilation flow and in fact may overcome or reverse the direction of flow of the mine ventilation system. During a mine fire, it is important for mine rescue personnel to measure the airflow to determine direction, quantity and quality.

4.4 Calculating Ventilation Flows

As mine rescue personnel advance through the mine during an emergency they may be required to calculate the ventilation flow in the mine. This may require them to determine direction and flow rates in cubic feet per minute (cfm). This process may require mine rescue personnel to use a velometer, anemometer, smoke tube, measuring tape and timing device, or other suitable technique.

Although the calculations are different for each measurement method, the results should be relatively close to each other.

Example 1: ….. A velometer measures 180 feet per minute (fpm) of air movement in a 15' x 18' opening, the calculation would be as follows:

180 fpm x (15 ft x 18 ft) = 48,600 cfm

Example 2:….. Using a smoke tube or dust particles and measuring an airflow of 20 ft. in 10 seconds in an opening of 15' x 18', the calculation would be as follows:

20 ft. x 6 sec. =120 fpm = Velocity 120 fpm x (15 ft x 18 ft) = 32,400 cfm

4.5 Ventilation Controls

It is important to control the amount and direction of air flow underground to ensure it is properly distributed to specified areas of the mine. Bulkheads, line brattice, regulators, and other control devices are necessary to assist with directing air throughout the mine.

4.5.1 Mine Doors

Mine doors are generally used to direct or stop air flow. Fire doors are usually installed at shaft stations or other strategic locations to serve as a barrier to fire, heat and contaminated air.

Mine doors are sometimes installed in sets / pairs to create an air lock preventing unnecessary air loss when one of the doors is opened to allow equipment or people to pass through. In order to maintain the air lock, doors should always be opened and closed one at a time.

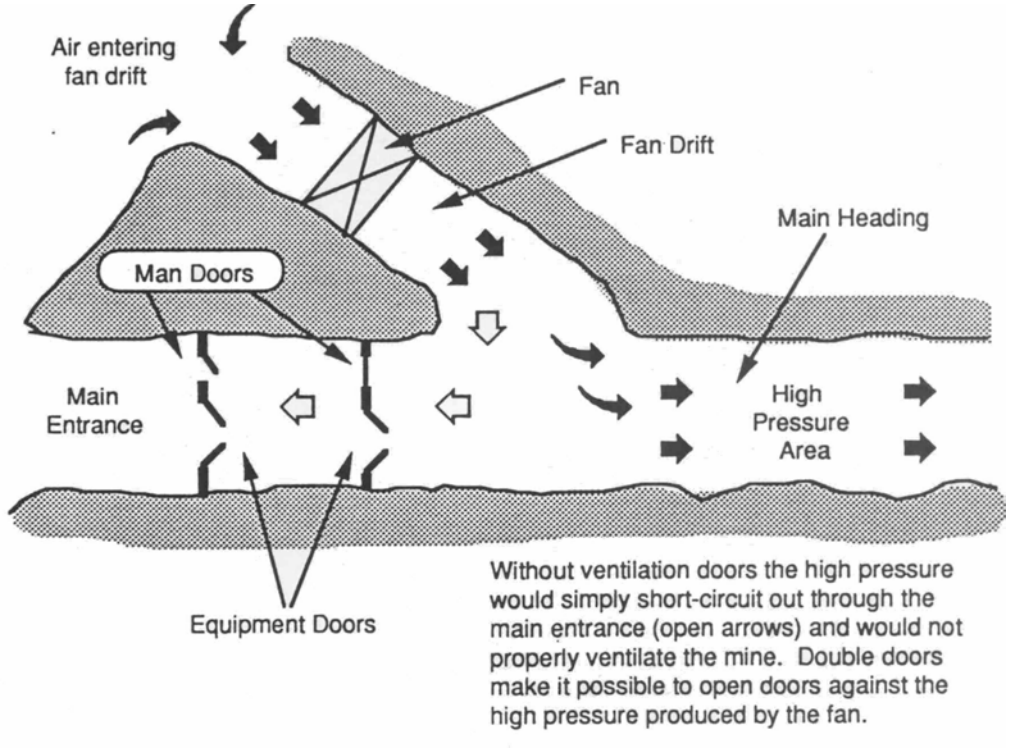
Air entering
fan drift
Fan
Fan Drift
Main Heading
Man Doors
Main
Entrance
High
Pressure
Area
Equipment Doors
Without ventilation doors the high pressure would simply short-circuit out through the main entrance (open arrows) and would not properly ventilate the mine. Double doors make it possible to open doors against the high pressure produced by the fan.

Figure 4.4 – Sample of Ventilation Control Using Mine Doors.

Mine doors are normally installed so the ventilating air pressure will maintain them in the closed position. Depending on their design, doors may be manually or mechanically controlled. It is important to ensure doors are properly maintained and operated.

4.5.2 Bulkheads

Bulkheads are permanent or temporary walls erected to direct air to where it is needed and to keep air from being short-circuited to the exhaust circuit before it reaches its intended destination.

(a) **Permanent Bulkheads** are built of concrete blocks or other non-combustible material. They are sealed tightly against the back, floor, and sides of a mine passage preventing air leakage. Permanent bulkheads may have a small door installed in them to allow personnel to pass through. In addition, some permanent bulkheads are built with a blast door in them. The blast door is designed to open and relieve pressure when there is blasting in the area.

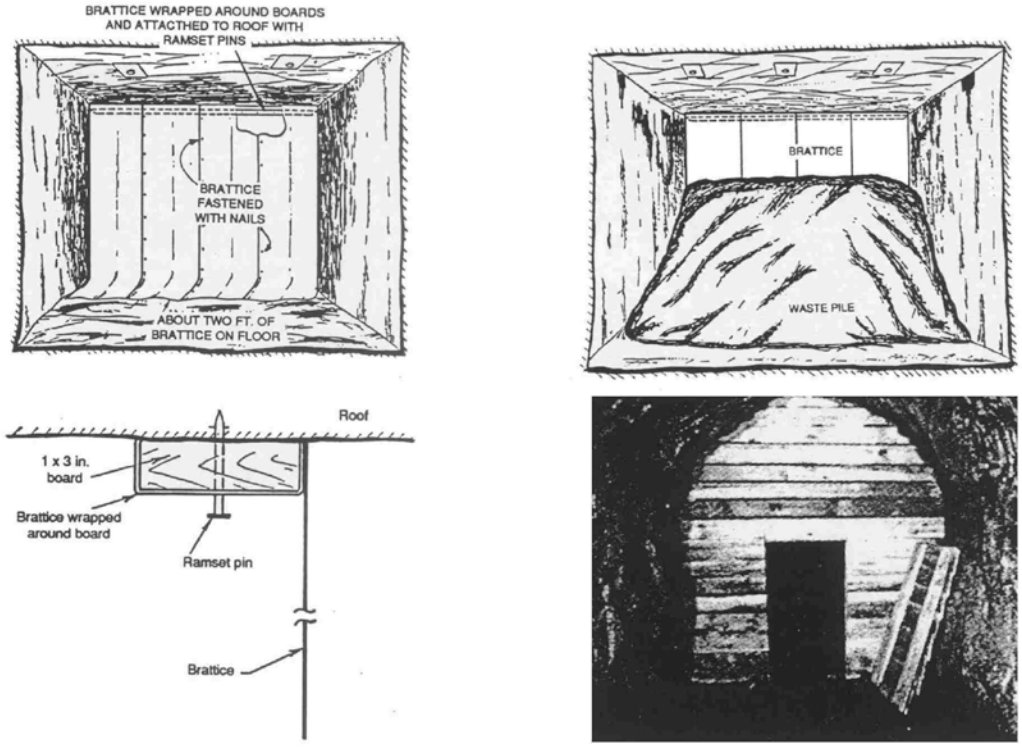

Figure 4.5 – Temporary bulkheads (left) sample of how to build a brattice bulkhead, (top right) bulkhead made using brattice & waste & (bottom right) wooden bulkhead built with a man door.

(b) **Temporary Bulkheads** are usually built of canvas, brattice cloth, plastic, wood or metal. In mine rescue work, temporary bulkheads are used to advance ventilation as the exploration or mine recovery work progresses. There are specially designed temporary bulkheads for use in mine rescue work which are fast and easy to install. Examples include inflatable, rubberized bladders and self-sealing "parachute stoppings."

(c) **Line Brattice** is woven cloth or plastic hung to split a main air current and channel part of it into a working area to provide ventilation. Line brattice usually extends from the back to the sill. It can be hung from a rough lumber frame, timber posts, messenger cable or from special fasteners.

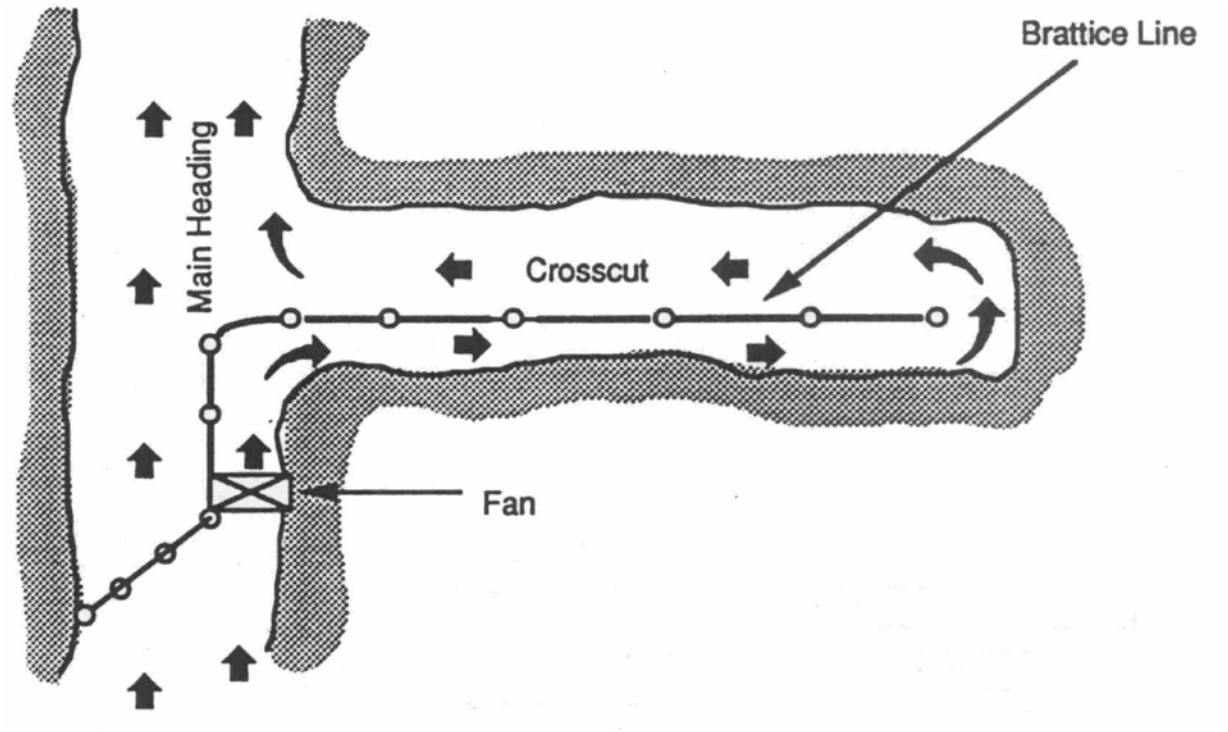

Figure 4.6 – Line brattice creates a split in the main airway and a second path for the air in the crosscut. Longer crosscuts may use a fan or carry the brattice right across the main airway (as shown above).

Mine rescue teams may, at times, find it necessary to use line brattice to direct ventilation to remove smoke or explosive gases from a mining area. If line brattice needs to hang only for a short time, the team can simply hold up the brattice, extending it into the area to be ventilated. In these situations, each team member should hold up a section of the line brattice and try to get it as close to the back as possible.

(d) **Regulators** may consist of a hinged or sliding door, flap or louver in a bulkhead or stopping. They are used to control air flow and may allow personnel to pass through without affecting the flow.

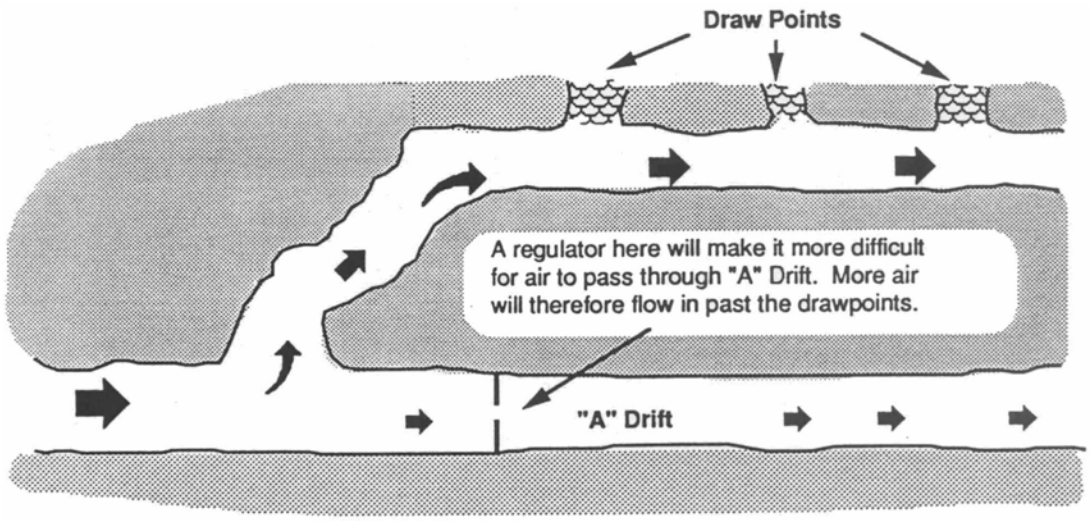
Draw Points
A regulator here will make it more difficult for air to pass through "A" Drift. More air will therefore flow in past the drawpoints.
"A" Drift

Figure 4.7 – A sample of a regulator to help supply air to a drift and allow air to flow along main drift.

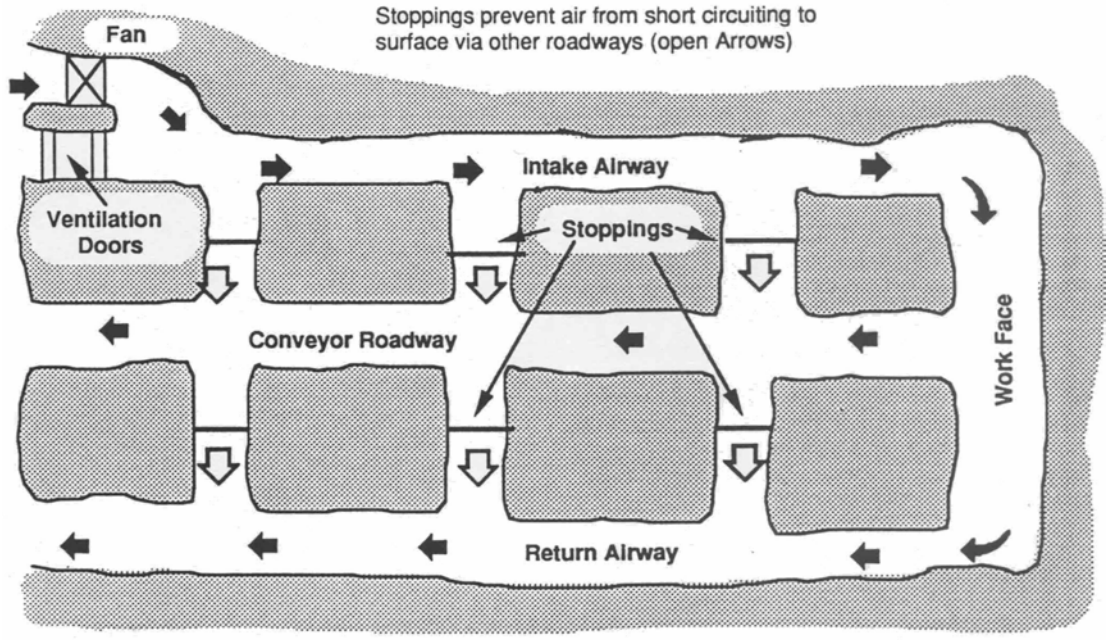

Figure 4.8 – Sample of the use of stoppings to direct air flow.

(e) **Auxiliary Fans and Tubing** can be used to either exhaust or supply air. Rigid and flexible ventilation tubing is used in conjunction with auxiliary fans.

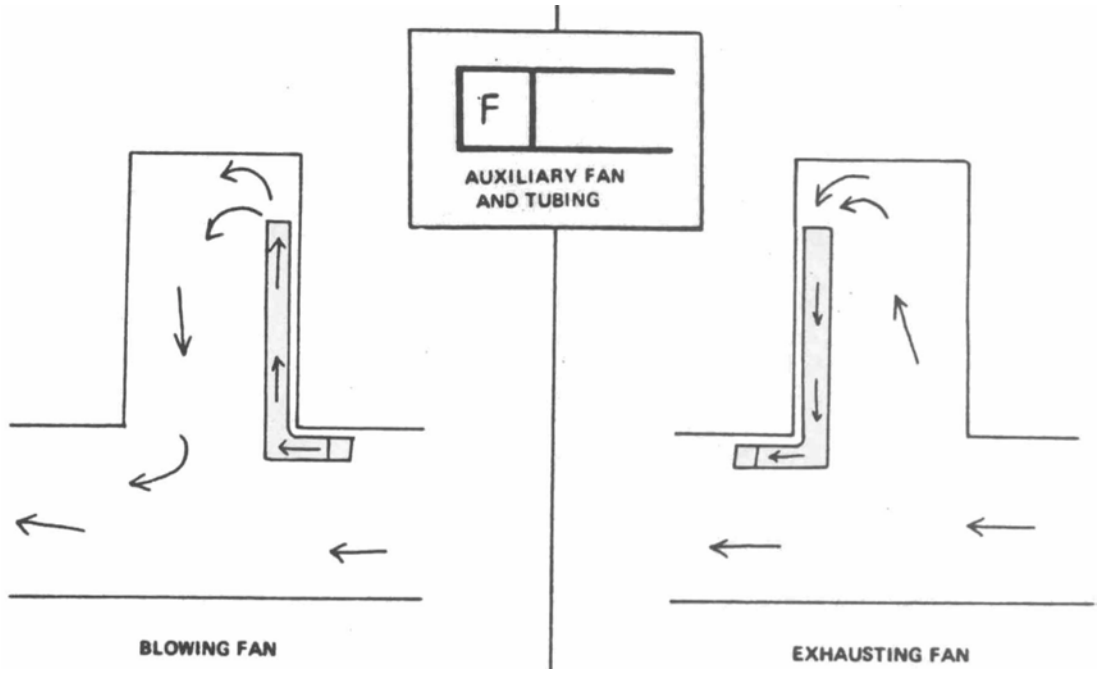

Figure 4.9 – Sample of secondary fans supplying air via vent tubing to heading or exhausting air to pull in the fresh air to the heading.

4.6 Building Ventilation Controls

Mine rescue and recovery work often involves re-establishing or altering ventilation in the mine, therefore it is necessary for rescue personnel to know how to build or install ventilation control devices.

Some members on a mine rescue team may not have experience at building or installing ventilation control devices. It is important all team members gain experience at this type of work during training sessions. Many tasks will be more difficult to achieve while team members are wearing breathing apparatus, working in reduced visibility or the nature of the emergency requires a sense of urgency.

(a) **Temporary Bulkheads** – When selecting the location for installing a temporary bulkhead, the mine rescue team must check rock surfaces to determine if the ground conditions are adequate for the installation of a temporary bulkhead. In order to provide a good seal around the bulkhead, it is important to ensure the back, walls and sill are free of loose material. Temporary bulkheads should be installed in a location where there is enough space to erect a permanent bulkhead at a later time.

There are many methods of installing bulkheads. Mine rescue teams must familiarize themselves with the various options and practice building or installing them. When determining what type to use, one must consider the size of the drift, location and distance from building materials etc. Temporary bulkheads can be constructed of plastic, fabrine or brattice cloth attached to a metal or wooden frame or the rock itself. Other methods of erecting a temporary bulkhead are by using inflatable bladders or installing parachutes in the ventilation stream.

A post or upright should be set at each side of the passageway when using a metal or wooden frame. If the passageway is wider, more uprights can be erected as required. Boards or cross members should be secured to the top and bottom of the uprights to allow for the attachment of the cover material. Surplus material at the bottom can be covered with rock and loose material.

If available, “pogo sticks”, which are spring loaded, expandable metal rods much like a pole lamp, can be utilized instead of wooden posts to erect temporary bulkheads. These temporary bulkheads could be built much faster, since they do not need to be cut and fitted. The “pogo sticks” could also be used along with uprights in wide passageways to reduce the number of uprights required.

If there has been an explosion in the mine, the mine rescue team may encounter a great deal of debris, damage to bulkheads, and hazardous ground conditions. In order to restore ventilation, teams might find it necessary to take whatever steps necessary to control ventilation.

Where there is material or equipment in the passageway, the team can hang brattice or plastic from the back and cut the brattice to fit around the piece of equipment or obstruction. Loose material can then be shovelled onto the excess brattice at the bottom and onto the equipment to create as tight a seal as possible.

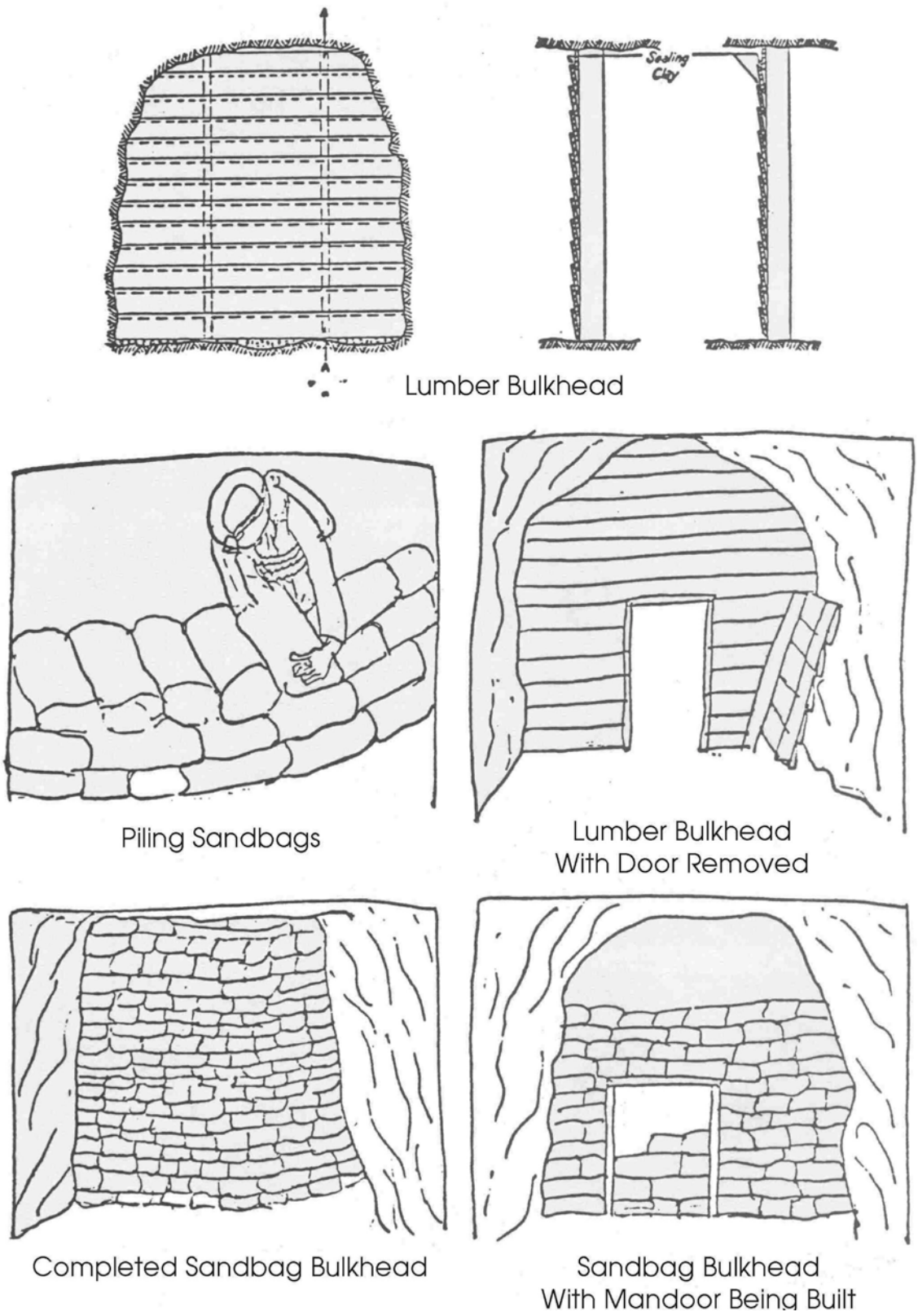

Figure 4.10 – Types of temporary bulkheads that may be built to change ventilation or seal a fire.

Another method being used in the building of seals is the use of a Hilti Drill to drill holes in the back and walls. Then using plastic inserts and Hilti nails with plastic, cardboard or thin plywood washers (2" X 2" approximately), erect the seal. The material used for the seal is usually a heavy plastic sheeting or brattice. The seal will in all likelihood not be strong enough to withstand an explosion but it will definitely be a good method to help change direction of ventilation or to provide a means of erecting a backup seal for the team or those in a refuge station. *(See Section 5.18 for further information on sealing mine fires)*

Through teamwork and practice and with the proper materials, a mine rescue team can erect adequate temporary bulkheads quickly and efficiently.

(b) **Permanent Bulkheads** – There are instances when permanent bulkheads are required. These may be erected to seal a fire permanently or impound water or material. Permanent bulkheads may be constructed of bricks concrete or other suitable material. Pressure resisting bulkheads should be designed and built to engineered specifications.

Permanent bulkheads should also be equipped with monitoring sites to measure air quality, pressure or other conditions behind the bulkhead.

(c) **Air Locks (Backup Seals)** – In today's reality, erecting air locks or back-up seals in development drifts or production areas is problematic due to their size and volume of air flow.

The importance of installing air locks or back-up seals must not be minimized since they may become a factor when a mine rescue team is required to pass through a door or bulkhead when conditions on the other side are unknown or to access personnel who have taken refuge behind a temporary or permanent barrier.

In these instances there are two considerations:

i) The mine rescue team may be required to pass through a barrier without erecting an air lock or back-up seal. If required, the mine rescue team must proceed in an orderly and systematic manner to ensure there is a minimum transfer of air or contaminant to either side of the barrier. This activity must be accomplished following pre-

determined entry procedures and ensuring the course of action does not compromise the safety and health of the team members or those who have taken refuge behind the barrier.

ii) The mine rescue team may be required to erect an airlock or back-up seal prior to passing through a barrier. When erecting an air lock or back-up seal the mine rescue team should receive their instruction from the Director of Operations or senior mine management. The construction of an airlock or back-up seal should adhere to good construction principles and follow the guidelines established previously in this section relating to the installation of permanent and temporary bulkheads.

Installing an airlock or back-up seal requires careful consideration to ensure they do not place personnel at unnecessary risk or cause the emergency response situation to become worse. At no time should an airlock or back-up seal be installed or dismantled without the approval of the Director of Operations or a representative of senior mine management.

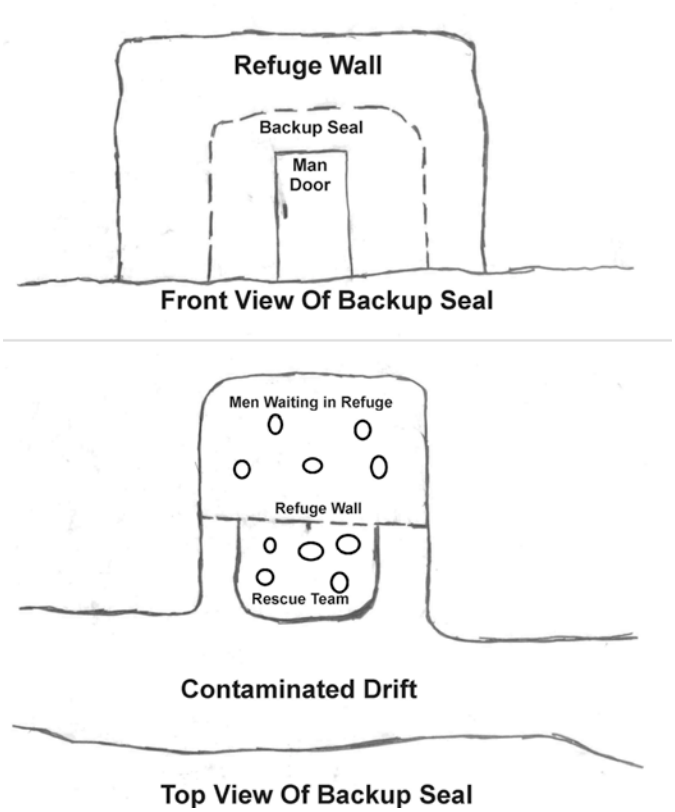

Figure 4.11 – An example of a seal that could be used by a team to rescue men from a refuge.

4.7 Review Questions

1) What are the two basic functions of the mine ventilation system?

2) What are three methods of providing ventilation in a mine? Explain the differences.

3) If you were asked to test direction of air currents in mine, and you did not have a smoke tube assembly, what could you do?

4) Determine airflow in a 9’ x 12’ drift using a smoke tube and measuring tape. The smoke travels 50' in 10 sec. What is the estimated CFM?

5) As a mine rescue team advances through the mine, why should they check the conditions of the compressed air system, record their observations on their map and report the information to the Director of Operations?

6) It is important to control the amount and direction of airflow in a mine to ensure proper distribution. List four ways this can be achieved.

7) Describe two types of bulkheads.

8) Should a bulkhead be constructed or a seal dismantled without the approval of the Emergency Control Centre? Explain.

LEARNING OBJECTIVES AND TARGET AUDIENCE

SECTION 5
FIRE

Learning Objectives

Section 5 deals with the cause of fire, how to prevent the occurrence of a fire and effective ways of extinguishing or minimizing the effects of fire.

Suggested Target Audience

Section Number	Topic	Basic Mine Rescue Trainees	Standard Mine Rescue Trainees	Advanced Mine Rescue Trainees	Mine Rescue Equipment Technicians	Mine Rescue Instructors	Director Of Operations & Resource Personnel	Senior Management Personnel	Supervisors	New Or Transferred Employees
5.1	Conservation Of Mass & Energy	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.2	Chemical Reaction	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.3	Combustion	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.4	Fire Tetrahedron	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.5	Fire Development	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.6	Factors That Affect Fire Development	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.7	Special Considerations	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.8	Products Of Combustion	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Suggested Target Audience (continued)

Section Number	Topic	Basic Mine Rescue Trainees	Standard Mine Rescue Trainees	Advanced Mine Rescue Trainees	Mine Rescue Equipment Technicians	Mine Rescue Instructors	Director Of Operations & Resource Personnel	Senior Management Personnel	Supervisors	New Or Transferred Employees
5.9	Factors Contributing To Industrial Fires	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.10	Fire Control & Extinguishing Methods	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.11	Fire Fighting	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.12	Classification Of Fires And Extinguishing	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.13	Portable Fire Extinguishers	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.14	Basic Steps For Fire Extinguisher	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.15	Classification Of Fire Extinguishers	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.16	Low & High Expansion Foam		**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
5.17	Site Specific Fire Procedures	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
5.18	Sealing Mine Fires		**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
5.19	Mine Recovery			**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
5.20	Re-establishing Ventilation After A Fire Or Explosion			**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
5.21	Un-sealing A Fire Area			**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
5.22	Review Questions	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			

Section 5. FIRE

To better understand fire and fire development we must leave the mine and look at fire as firefighters look at fires and study the characteristics and phases of fire as they do.

The information being used is from the International Fire Service Training Association (IFSTA) manual - Essentials of Firefighting 4th Edition.

5.1 Conservation Of Mass And Energy

As a fire burns, the fire consumes fuel and as a result, its mass is reduced.

Modern Physical Science defines this as *"The Law of Conservation of Mass".* The law states mass and energy may be converted from one to another, but there is never any net loss of total mass-energy. In other words, mass and energy are neither created nor destroyed. This law is fundamental to the science of fire. This means when there is a reduction in the fuel (burning) there will be a release of energy in the form of light and heat.

When preplanning or sizing up a fire scene, the personnel entering the fire scene must realize the more fuel there is, the greater the amount of energy there will be released. This will ultimately affect how much extinguishing agent will be required to control the fire.

5.2 Chemical Reaction

Before the discussion of combustion and fire growth begins, it must be understood what the concept of chemical reactions are. Scientists describe a chemical reaction as whenever matter is transformed from one state to another or a new substance is produced.

A simple form of this would be physical change where the chemical makeup of the substance is not altered. For example when water freezes there is only a physical change.

A more complex reaction occurs when substances are transformed into new substances with different physical and chemical properties. These changes are defined as chemical changes. A good example of this would be when Hydrogen and Oxygen are combined to form water.

Physical and chemical changes almost always involve an exchange of energy. Reactions that give off energy as they occur are called exothermic. Reactions that absorb energy as they occur are called endothermic. An example of an exothermic reaction is when fuels are burned in air. Fuel vapors mix with oxygen in air, and heat and light energies are given off. Water being changed to steam requires the input of energy (heat) thus it is an endothermic reaction.

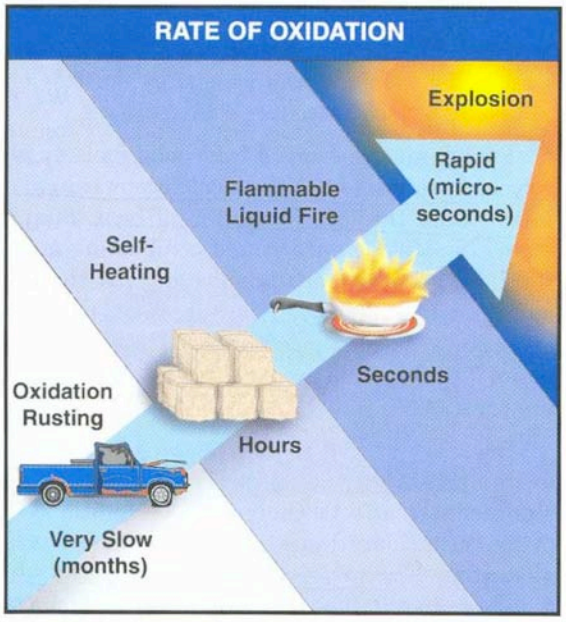

Figure 5.1 – Combustion, A Self-Sustaining Chemical Reaction, May Be Very Slow Or Very Rapid

One of earth's most common chemical reactions is oxidation. Oxidation is defined as the formation of a chemical bond between oxygen and another element. Oxidation is exothermic and one of the most familiar examples of this is iron oxide or rust. Normally this happens slowly so that it is not noticed. But, when a ship carrying iron filings in the confined spaces of the hull, the oxidation occurs and the heat builds up but is dissipated by the ship moving through the waters. When the ship is docked and the oxidation is occurring it has been seen that the water is boiling by the hull of the ship because the heat is not dissipated through the water movement. This reaction is quite dramatic to see but rarely ever gets to the point of ignition.

5.3 Combustion

Fire and combustion are terms are often used interchangeably. Technically fire is a form of combustion.

Combustion is a self-sustaining chemical reaction yielding energy or products that cause further reaction of the same kind.

Combustion is an exothermic reaction. Fire is a rapid, self-sustaining oxidation process accompanied by evolution of heat and light of varying intensities.

To sum it up the time it takes a reaction to occur determines the type of reaction observed. On the slow end of the spectrum is oxidation. At the fast end of the

spectrum is an explosion resulting from a very rapid reaction of fuel and an oxidizer and of course this results in a tremendous release of energy in a very short time.

5.4 Fire Tetrahedron

For many years, the three-sided figure of the fire triangle (oxygen, fuel and heat) was used to teach the components of fire. While this simple example is useful, it is not technically correct. For combustion to occur, four components are necessary:

- Oxygen (oxidizing agent)
- Fuel
- Heat
- Self-sustained chemical reaction

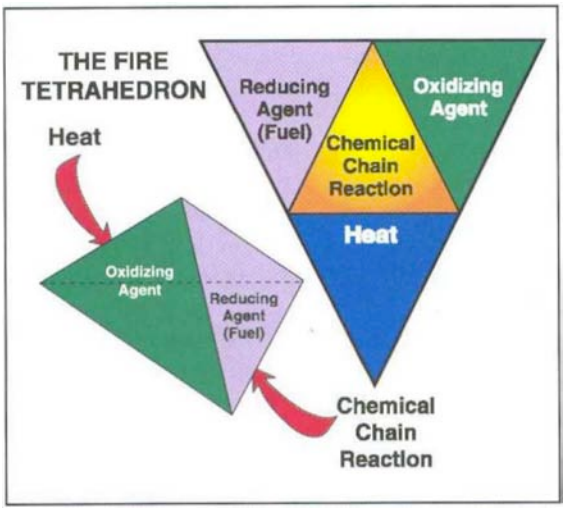

Figure 5.2 – The Fire Tetrahedron

These four elements form the fire tetrahedron. Each component of the tetrahedron must be in place for combustion to occur. It is important to remember, when one of the components is removed, combustion will not occur. This forms the basis of extinguishing a fire.

To better understand fire and its behavior, the four components of the tetrahedron are described, as follows:

5.4.1 **Oxygen** (Oxidizing Agent)

Oxidizing agents are materials yielding oxygen or other oxidizing gases during the course of a chemical reaction. Oxidizers are not combustible, but they support combustion when combined with a fuel. While oxygen is the most common oxidizer, other common oxidizers include; bromates, bromine, chlorates, chlorine, fluorine, iodine, nitrates, nitrites, nitric acid, perchlorates, permanganates and peroxides. For the purposes of mine rescue, the oxygen in the air around us is considered the primary oxidizing agent.

Air containing 21% O_2 readily supports combustion. Research has found air containing as little as 14% O_2 will support combustion in a confined space at room temperature (21° C).

An atmosphere containing over 21% O_2 is considered to be O_2 enriched and this can cause other serious situations.

Materials that burn at normal levels will burn more quickly. Some materials will not burn at normal Oxygen levels, but will burn in an Oxygen enriched atmosphere.

Nomex is one such material which will ignite and burn vigorously in an atmosphere of 31% Oxygen. This is highly unlikely to happen in a mine fire, but Mine Rescue personnel do use Oxygen CCBA's and thus a leak of Oxygen from the unit could put themselves personally in danger of a localized Oxygen enriched atmosphere.

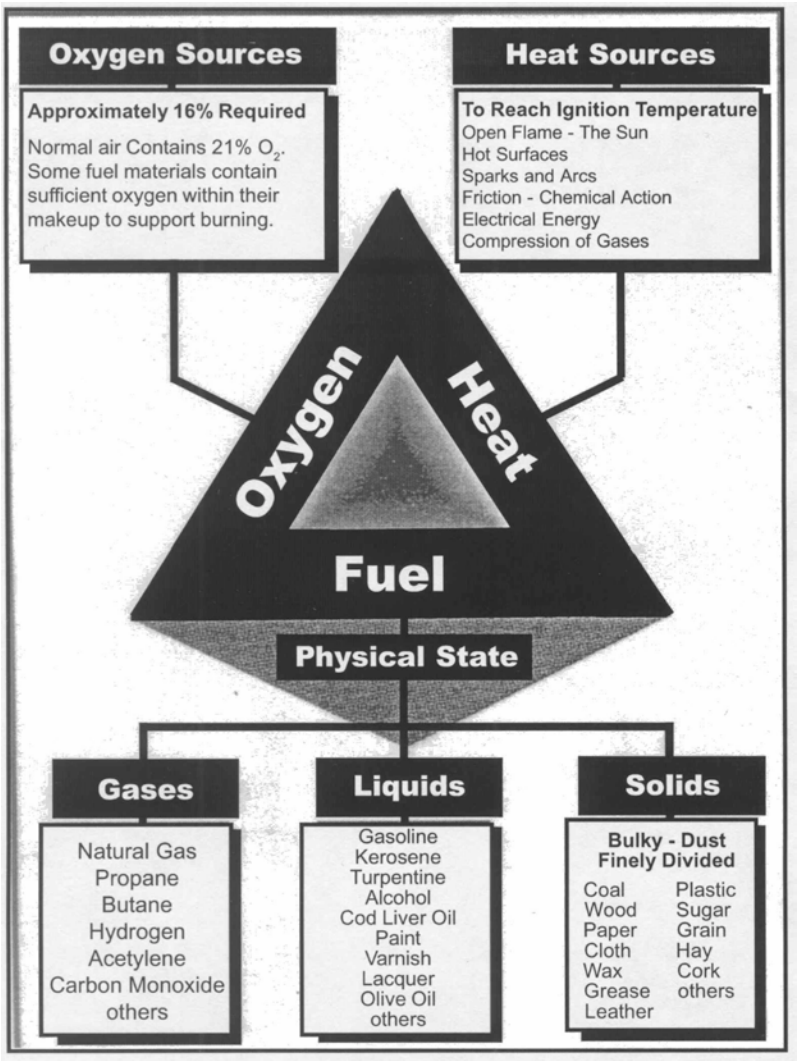

Figure 5.3 – Illustration of components necessary for combustion to occur.

5.4.2 Fuel

Fuel is the material or substance being oxidized or burned in the combustion process. Scientifically the fuel in the combustion reaction is known as the "reducing agent". Most common fuels contain carbon along with combinations of Hydrogen and Oxygen. This can then be broken down further with fuels like gasoline, diesel fuel or plastics which are hydrocarbon based. Fuels such as wood or paper are considered cellulose based

materials. The combustion process involves two key fuel-related factors, the physical state of the fuel and the fuel distribution.

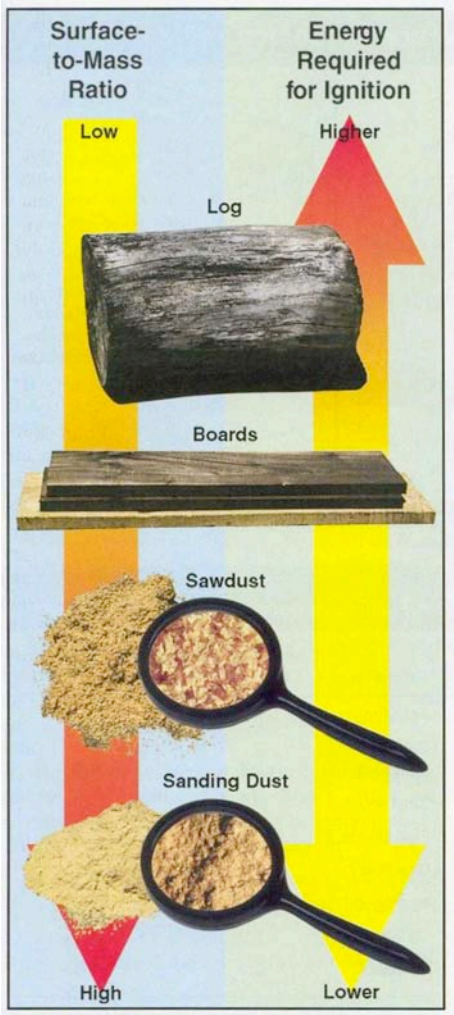

Figure 5.4 – Surface To Mass Ratio Illustration For Wood

Fuel may be found in three states: solids, liquids or gases. To burn however, fuels must be in the gaseous state. For solids and liquids, heat must be applied in order to cause a chemical composition capable of changing the solid or liquid into a gaseous state.

Fuel gases are evolved from solid fuels by pyrolysis. Pyrolysis is the chemical decomposition of a substance through the action of heat. Simply stated, as solid fuels are heated, combustible materials are driven from the substance. When sufficient fuel and heat are present, pyrolysis will generate sufficient quantities of burnable gases to ignite if the other elements of the tetrahedron are present.

Solid fuels have a definite size and shape. This property affects the ease of ignition. Of primary considerations is the surface to mass ratio, which is the surface area of the fuel in proportion to the mass. One good example of this is wood. Consider that to make wood useful, the tree must be cut into logs (high mass, but low surface area). Surface to mass ratio is low and this makes it hard to ignite. Logs are milled into boards (mass is reduced, surface area is increased). Surface to mass ratio is increased thus not as hard to ignite. The sawdust from the milling of the boards (less mass and more surface area). Surface to mass ratio is increased and much easier to ignite). If the boards are sanded the resulting sanding dust has the highest surface to mass ratio (large surface area, least mass, and is very easy to ignite).

To sum this up, as the surface area increases, more of the material is exposed to the heat and thus generates more burnable gases due to pyrolysis.

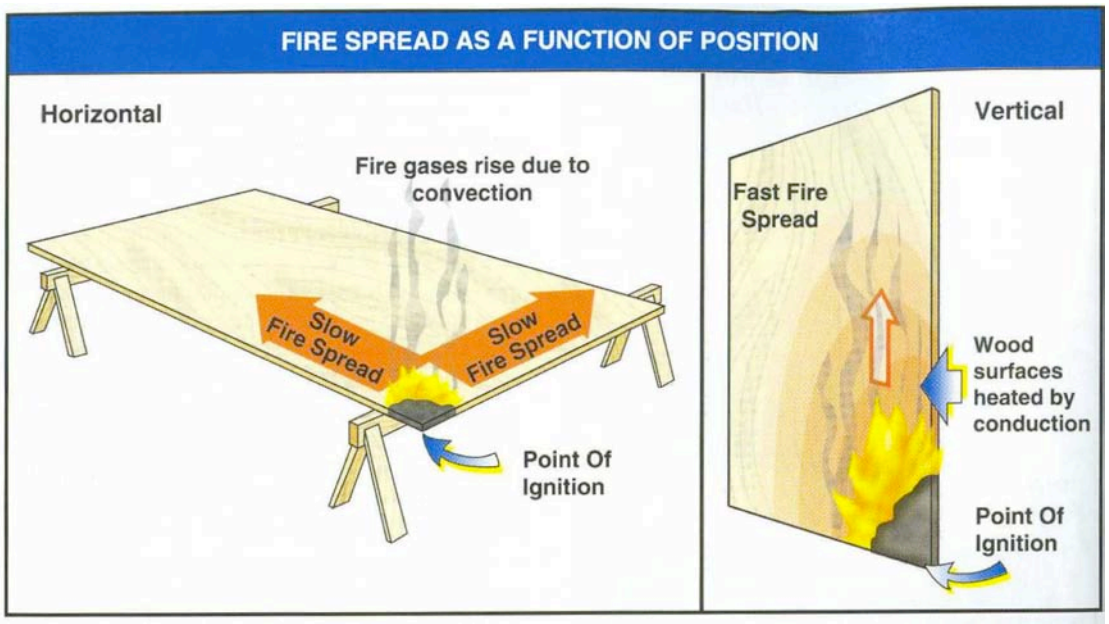

Figure 5.5 – Position Of Solid Fuel Affects The Way It Burns

The position of the solid fuel also affects the way it burns. When a solid fuel is placed vertically it will burn quicker. Lay the fuel horizontal and the fire spread is slowed down. This happens because of the increased heat transfer through convection as well as conduction and radiation when the fuel is vertical.

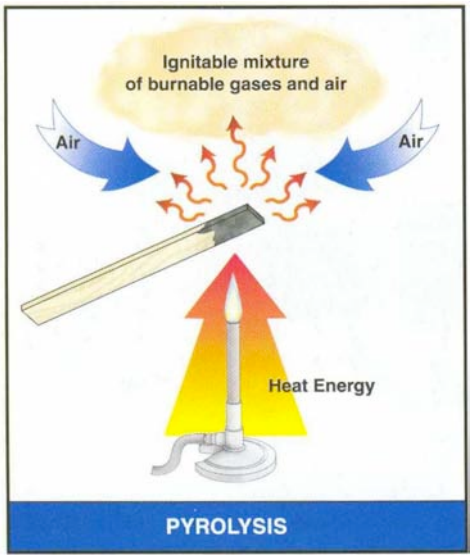

Figure 5.6 - Pyrolysis Takes Place As The Wood Decomposes From The Action Of The Heat-Generating Vapors. These Vapors Then Mix With Air, Producing An Ignitable Mixture.

For liquid fuels gases are produced by vaporization, which in scientific terms means the transformation of a liquid to its vapor or gaseous state. This occurs when molecules of the substance break free from the substance's surface into the surrounding atmosphere. For this to occur some form of energy must be applied. The most common source of energy is heat.

Think of water in a pan and leave it in a room. It will slowly evaporate using the energy from the room temperature and the sun. Put the pan on a stove and apply heat and the reaction will happen more quickly. The rate of vaporization is dependent on the substance and the amount of heat or energy applied to it.

Of course vaporization usually requires less energy input than pyrolysis for solid fuels and liquids. The volatility or ease with which a liquid gives off vapors effects the ignitability. All liquids give off vapors due to evaporation.

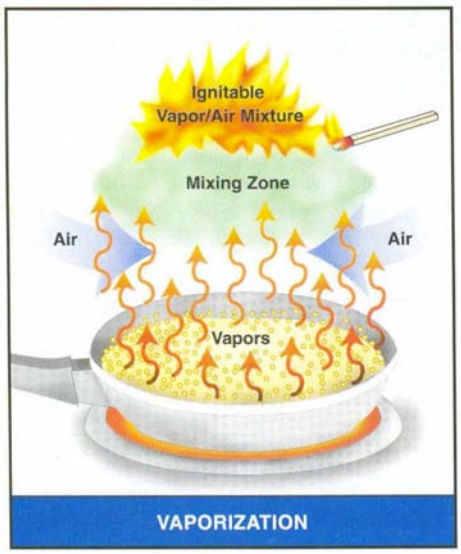

Figure 5.7 - Vaporization Occurs As Fuel Gases Are Generated From The Action Of Heat. These Vapors Then Mix With Air, Producing An Ignitable Mixture.

Like surface to mass ratio for solid fuels, surface to volume ratio affects the ignitability of a liquid. To put it simply, if there is a liquid spill or release and it flows onto the ground, it will assume the shape of the ground (flat) and therefore it has a greater surface to volume ratio and this increases the amounts of fuel vapors that are released. This compares to a container that confines the surface area of the fuel and less vaporization will occur.

For combustion to occur after a fuel has been converted to a gaseous state, it must be mixed with air (oxidizer) in the proper ratio. This range, as we know it is the “flammable” (explosive) range. This range is reported in percentages. We use the terms lower explosive level (LEL) and upper explosive level (UEL). Concentrations below the LEL are too lean to burn or explode and concentrations above the UEL are too rich to burn or explode.

The ranges are usually reported using ambient temperatures and atmospheric pressures. Variations in temperature and pressure can cause these ranges to vary considerably. To generalize increases in temperature and pressure broaden the ranges and decreases narrow the ranges.

5.4.3 Heat

Heat is the energy component of the fire tetrahedron. When heat comes in contact with a fuel, the energy supports the combustion reaction in the following ways:

- causes the pyrolysis or vaporization of solid and liquid fuels and the production of ignitable vapors and gases.
- provides the energy necessary for ignition.
- causes the continuous production and ignition of fuel vapors or gases so that the combustion reaction can continue.

Most of the energy types that have been discussed produce heat. When discussing fire and its behavior, the most common sources of heat that result in ignition of fuels are chemical, electrical and mechanical energy. These sources and other will be discussed later in this section.

5.4.4 Self-Sustained Chemical Reaction

Combustion is a complex reaction that requires a fuel (in a gaseous or vapor state), an oxidizer and heat energy to come together in a very specific manner. Once fire occurs, it can only continue when enough heat energy is produced to cause the continued development of fuel or vapor gases. This process is commonly referred to as a chain reaction or a series of activities that occur in sequence with the results of each reaction or event adding to the rest.

An example of a chain reaction is a forest fire. The heat from one tree may initiate the chemical reaction (burning) of a second tree, which in turn ignites a third, and so on. But, if one tree ignites two others, and each of these two ignites two more, for a total of four, and so on the rate of burning escalates at an incredible pace.

The self-sustained chemical reaction and the related rapid growth are the factors that separate fire from the slower oxidation processes.

5.5 Fire Development

When the four components of the fire tetrahedron come together, ignition occurs. For a fire to grow beyond the first material ignited, heat must be transmitted beyond the first material to additional fuel packages. In the early development of afire, heat rises and forms a plume of hot gas. If a fire is in the open (outside or in a large building), the fire plume rises unobstructed, and air is drawn(entrained) into it as it rises. Because the air being pulled into the plume is cooler than the fire gases, this action has a cooling effect on the gases above the fire. The spread of fire in an open area is primarily due to heat energy that is transmitted from the plume to nearby fuels. Fire spread in outside fires can be increased by wind and sloping terrain that allow exposed fuels to be preheated.

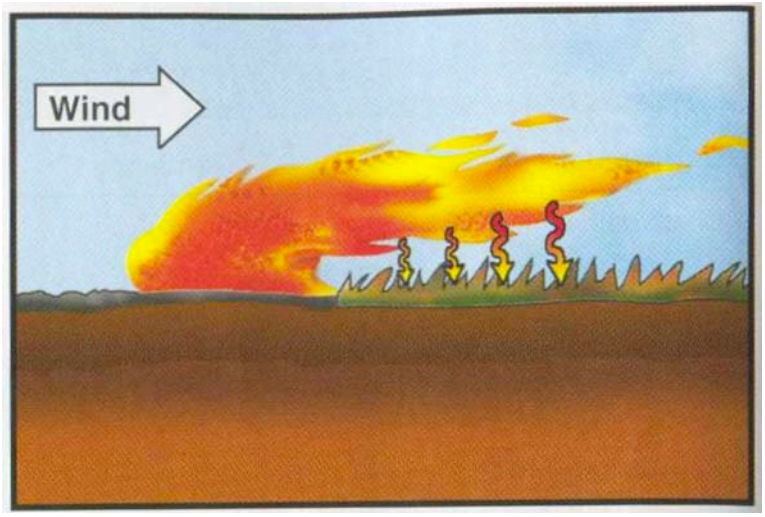

Figure 5.8 – Outdoor Fire Spread Is Effected By Wind And Terrain

The development of fires in a compartment is more complex than those in the open. For the purposes of this discussion, a compartment is an enclosed room or space. The term compartment fire is defined as a fire that occurs within such a space. The growth and development of a compartment fire is usually controlled by the availability of fuel and oxygen. When the amount of fuel available to burn is limited, the fire is said to be fuel controlled. When the amount of available oxygen is limited, the condition is said to be ventilation controlled.

Recently, researchers have attempted to describe compartment fires in terms of stages or phases that occur as the fire develops. These stages are as follows:

- Ignition
- Growth
- Flashover
- Fully developed
- Decay

5.5.1 Ignition

Ignition describes the time when the four elements of the tetrahedron come together and combustion begins. The physical act of ignition can be piloted (caused by a spark or flame) or non-piloted (caused when a material reaches its ignition point as a result of self-heating) like spontaneous ignition. At this point the fire is small and confined to the materials (fuel) that first ignited. All fires occur because of some type of ignition.

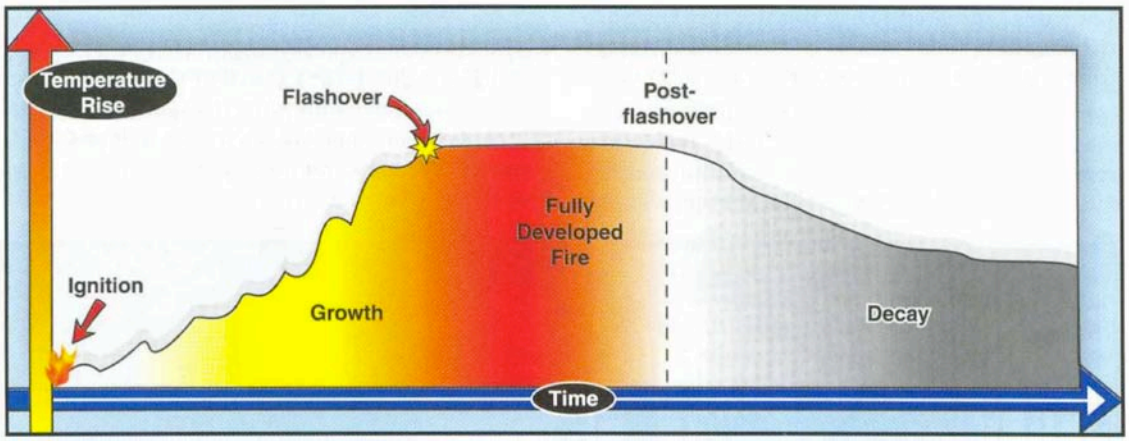

Figure 5.9 - Stages Of Fire Development In A Compartment.

5.5.2 Growth

Shortly after ignition, a fire plume begins to form above the burning fuel. As the plume develops, it begins to draw or entrain air from the surrounding space into the column. The initial growth is similar to that of an outside unconfined fire, with the growth a function of the fuel first ignited. Unlike an unconfined fire, however, the plume in a compartment is rapidly affected by the ceiling and walls of the space. The location of the fuel package will have an affect on the temperature of the fire and the amount of air entrained. This will significantly affect the temperatures of the developing gas layer above the fire. As the hot gases rise, they begin to spread outward when they hit the ceiling. The gases continue to spread until they reach the walls of the compartment. The depth of the gas layer then begins to increase.

The growth stage will continue if enough fuel and oxygen are available. Compartment fires in the growth stage are generally fuel controlled. As the fire grows, the overall temperature in the compartment increases as does the temperature of the gas layer at the ceiling level.

5.5.3 Flashover

Flashover is the transition between the growth and the fully developed fire stages and is not a specific event such as ignition. During flashover, conditions in the compartment change very rapidly as the fire changes from one that is dominated by the burning of the materials first ignited to one that involves all of the exposed combustible surfaces within the compartment. The

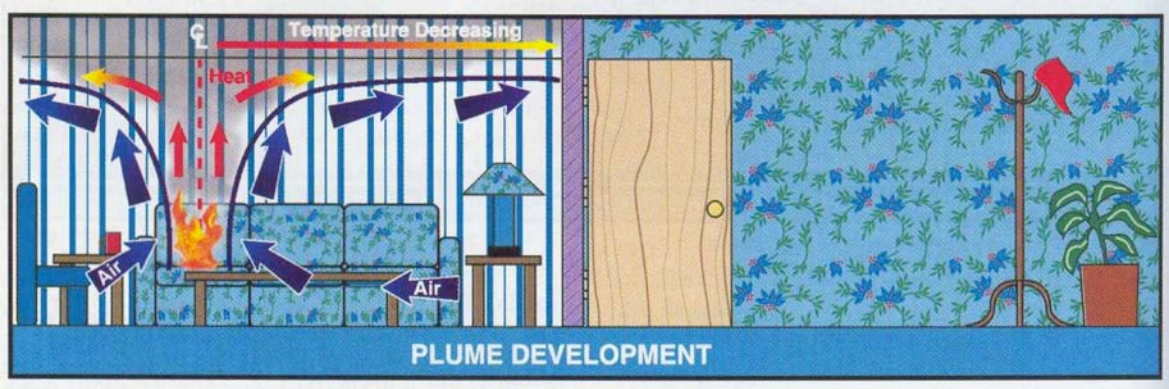

Figure 5.10 -Initially, The Temperature Of The Fire Gases Decreases As They Move Away From The Centerline Of The Plume.

hot-gas layer that develops at the ceiling level during the growth stage causes radiant heating of combustible materials remote from the origin of the fire. This radiant heating causes pyrolysis in the combustible materials in the compartment. The gases generated during this time are heated to their ignition temperature by the radiant energy from the gas layer at the ceiling.

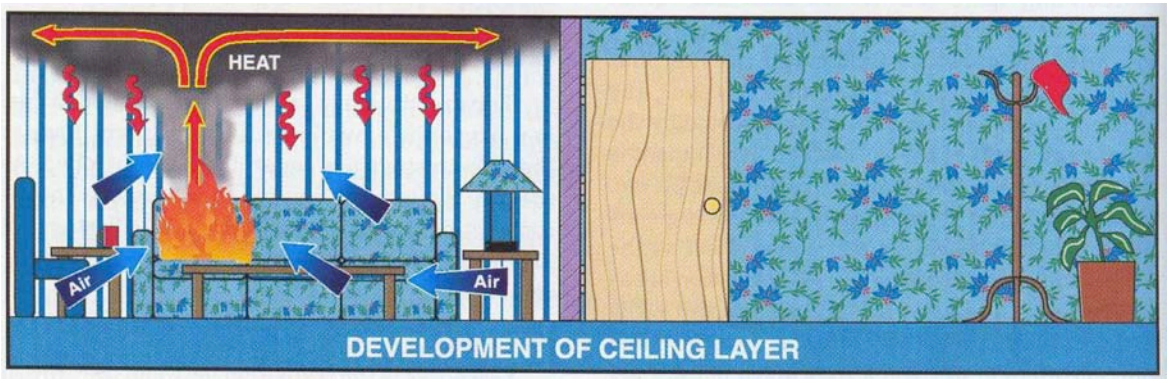

Figure 5.11 -As The Fire Grows, The Overall Temperature In The Compartment Increases As Does The Temperature Of The Gas Layer At The Ceiling Level.

While scientists define flashover in many ways, most base their definition on the temperature in a compartment that results in the simultaneous ignition of all of the combustible contents in the space. While no exact temperature is

associated with this occurrence, a range from approximately 900°F to 1,200°F (483°C to 649°C) is widely used. This range correlates with the ignition temperature of carbon monoxide (CO) (1,128°F or 609°C), one of the most common gases given off from pyrolysis.

Just prior to flashover, several things are happening within the burning compartment:

- The temperatures are rapidly increasing,
- additional fuel packages are becoming involved,
- and the fuel packages in the compartment are giving off combustible gases as a result of pyrolysis.

Figure 5.12 -The Radiant Heat (Downward Curly Arrows) From The Hot-Gas Layer At The Ceiling Heats Combustible Materials, Which Produces Vapors (Upward Curly Arrows).

As flashover occurs, the combustible materials in the compartment and the gases given off from pyrolysis ignite. The result is full-room involvement. The heat release from a fully developed room at flashover can be on the order of 10,000 kW or more.

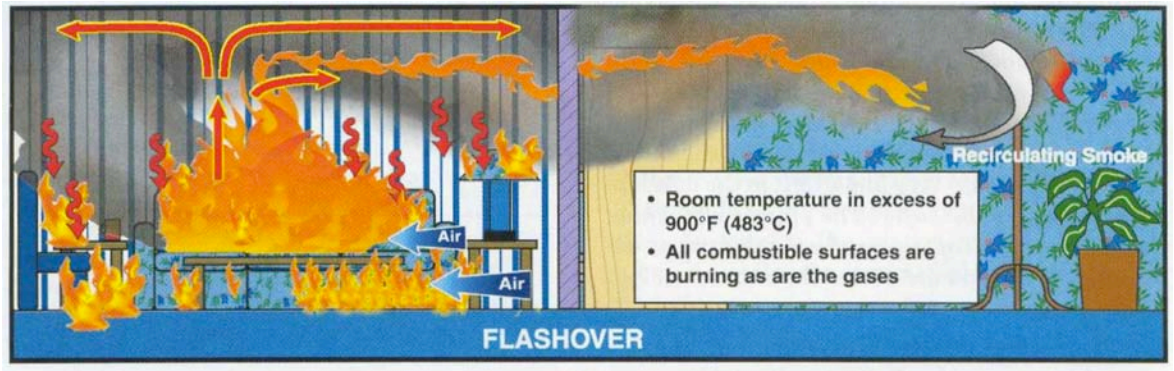

Figure 5.13 -An Example Of Flashover.

Occupants who have not escaped from a compartment before flashover occurs are not likely to survive. Firefighters who find themselves in a compartment at flashover are at extreme risk even while wearing their personal protective equipment.

5.5.4 Fully Developed

The fully developed fire stage occurs when all combustible materials in the compartment are involved in fire. During this period of time, the burning fuels in the compartment are releasing the maximum amount of heat possible for the available fuel packages and producing large volumes of fire gases. The heat released and the volume of fire gases produced depends on the number and size of the ventilation openings in the compartment. The fire frequently becomes ventilation controlled, and thus large volumes of unburned gases

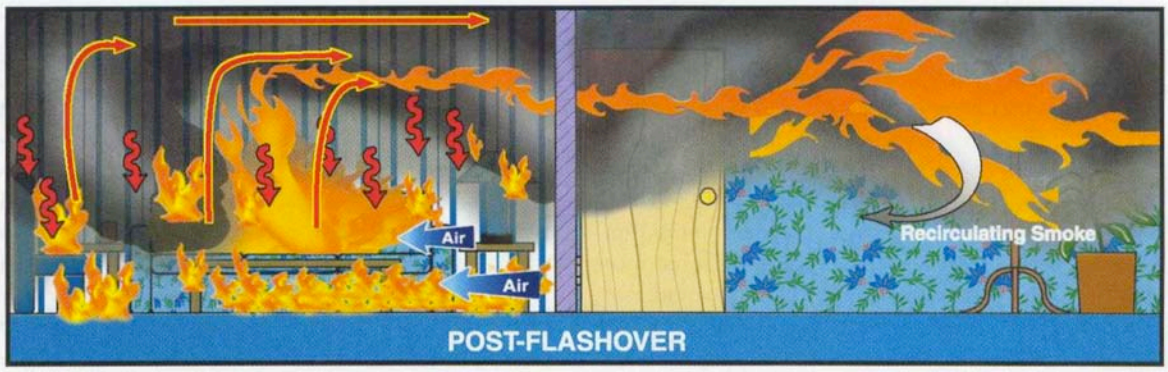

Figure 5.14 -A Fully Developed Fire.

are produced. During this stage, hot unburned fire gases are likely to begin flowing from the compartment of origin into adjacent spaces or compartments. These gases ignite as they enter a space where air is more abundant

5.5.5 Decay

As the fire consumes the available fuel in the compartment, the rate of heat release begins to decline. Once again the fire becomes fuel controlled, the amount of fire diminishes, and the temperatures within the compartment begin to decline. The remaining mass of glowing embers can, however, result in moderately high temperatures in the compartment for some time.

5.6 Factors That Affect Fire Development

As the fire progresses from ignition to decay, several factors affect its behavior and development within the compartment:

- Size, number, and arrangement of ventilation openings
- Rate and volume of ventilation flow
- Volume of the compartment
- Thermal properties of the compartment enclosures
- Ceiling height of the compartment
- Size, composition, and location of the fuel package that is first ignited
- Availability and locations of additional fuel packages (target fuels)

For a fire to develop, enough air to support burning beyond the ignition stage must be available. The size and number of ventilation openings in a compartment determine how the fire develops within the space. The compartment's size and shape and ceiling height determine if a significant hot-gas layer will form.

The temperatures that develop in a burning compartment are the direct result of the energy released as the fuels burn. Because matter and energy are conserved, any loss in mass caused by the fire is converted to energy. In a fire, the resulting energy is in the form of heat and light.

One final relationship between the heat generated in a fire and fuel packages is the ignition of additional fuel packages that are remote from the first package ignited. The heat generated in a compartment fire is transmitted from the initial fuel package to other fuels in the space by all three modes of heat transfer. The heat rising in the initial fire plume is transported by convection. As the hot gases travel over surfaces of other fuels in the compartment, heat is transferred to them by conduction. Radiation plays a significant role in the transition from a growing fire to a fully developed fire in a room. As the hot-gas layer forms at the ceiling, hot particles in the smoke begin to radiate energy to the other fuel packages in the compartment. These remote fuel packages are sometimes called target fuels. As the radiant energy increases, the target fuels begin pyrolysis and start to give off ignitable gases. When the temperature in the compartment reaches the ignition temperature of these gases, the entire room becomes involved in fire (flashover).

5.7 Special Considerations

Several situations or conditions that can occur during a fire's growth and development require discussion and this section will give an overview and some safety concerns for each item.

5.7.1 Flameover / Rollover

The terms Flameover and rollover describe a condition where flames move through or across the unburned gases during a fire's progression. Flameover is distinguished from flashover by its involvement of only the fire gases and not the surfaces of other fuel packages within a compartment. This condition may occur during the growth stage as the hot-gas layer forms at the ceiling of the compartment. Flames may be observed in the layer when the combustible gases reach their ignition temperature. While the flames add to the total heat generated in the compartment, this condition is not flashover. Flameover may also be observed when unburned fire gases vent from a compartment during the growth and fully developed stages of a fire's development. As these hot gases vent from the burning compartment into the adjacent space, they mix

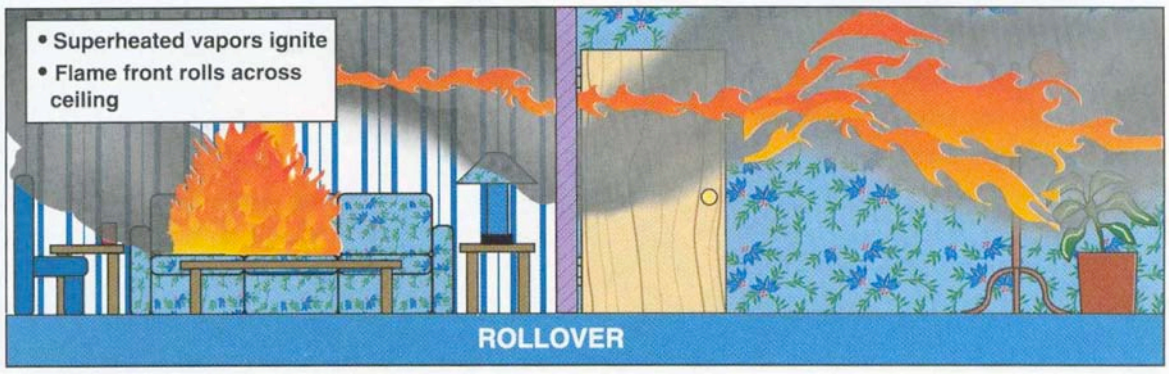

Figure 5.15 -An Example Of Rollover.

with oxygen; if they are at their ignition temperature, flames often become visible in the layer

5.7.2 Thermal Layering Of Gases

The thermal layering of gases is the tendency of gases to form into layers according to temperature. Other terms sometimes used to describe this tendency are heat stratification and thermal balance. The hottest gases tend to be in the top layer, while the cooler gases form the lower layers. As long

as the hottest air and gases are allowed to rise, the lower levels will be safer for firefighters.

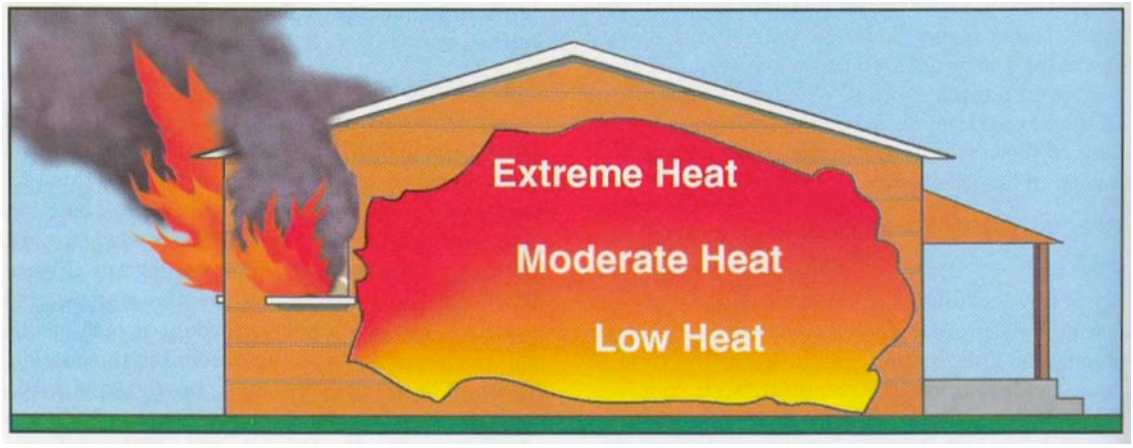

Figure 5.16 - Under Normal Fire Conditions In A Closed Structure, The Highest Levels Of Heat Will Be Found At Ceiling Level, And The Lowest Level Of Heat Will Be Found At Floor Level.

This normal layering of the hottest gases to the top and out the ventilation opening can be disrupted if water is applied directly into the layer. When water is applied to the upper level of the layer, where the temperatures are highest, the rapid conversion to steam can cause the gases to mix rapidly. This swirling mixture of smoke and steam disrupts normal thermal layering,

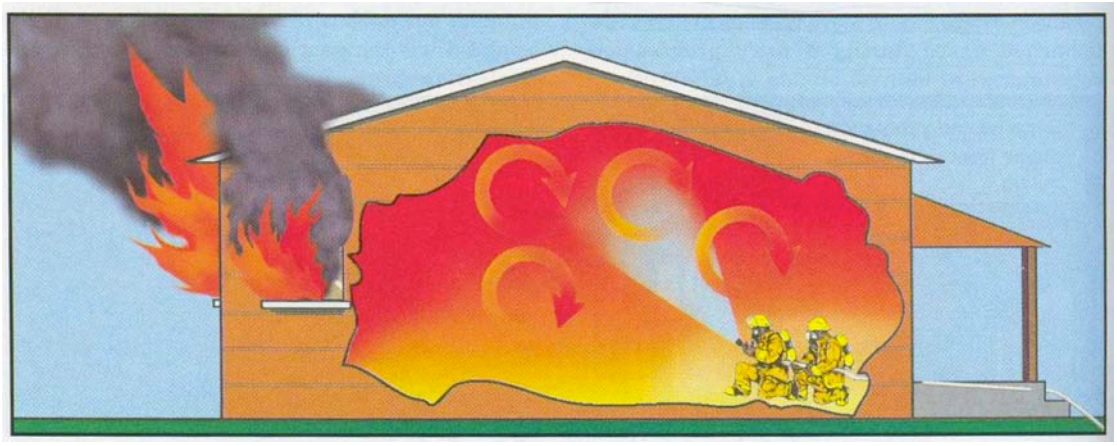

Figure 5.17 - Applying Water To The Upper Level Of The Thermal Layer Creates A Thermal Imbalance.

and hot gases mix throughout the compartment. Many firefighters have been burned when thermal layering was disrupted.

The proper procedure under these conditions is to ventilate the compartment, allow the hot gases to escape, and direct the fire stream at the base of the fire, keeping it out of the hot upper layers of gases.

5.7.3 Backdraft

Firefighters operating at fires in buildings must use care when opening a building to gain entry or to provide horizontal ventilation (opening doors or windows). As the fire grows in a compartment, large volumes of hot, unburned fire gases can collect in unventilated spaces. These gases may be at or above their ignition temperature but have insufficient oxygen available to actually ignite. Any action during fire fighting operations that allows air to mix with these hot gases can result in an explosive ignition called backdraft. Many firefighters have been killed or injured as a result of backdrafts. The potential for backdraft can be reduced with proper vertical ventilation (opening at highest point) because the unburned gases rise.

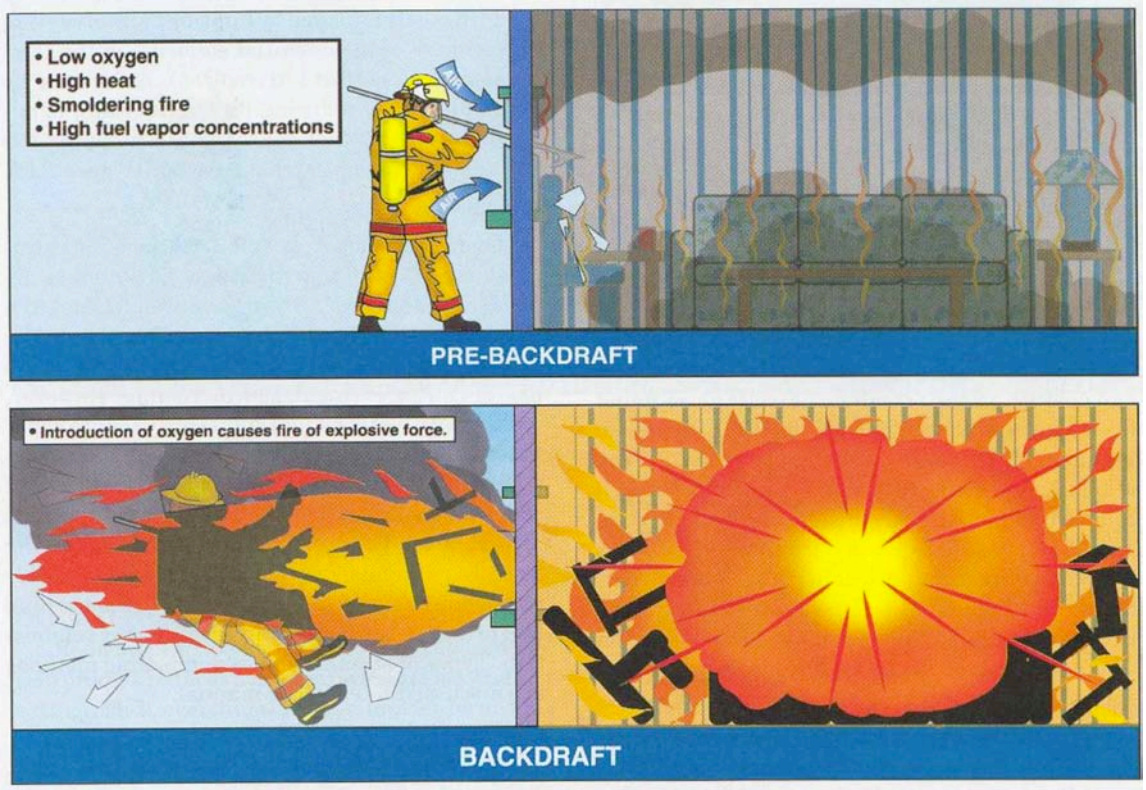

Figure 5.18 - Improper ventilation during fire fighting operations may result in a backdraft.

The following conditions may indicate the potential for a backdraft:

- Pressurized smoke exiting small openings
- Black smoke becoming dense gray yellow
- Confinement and excessive heat
- Little or no visible flame

- Smoke leaving building in puffs orintervals (appearance of breathing)
- Smoke-stained windows

5.8 Products Of Combustion

As a fuel burns, the chemical composition of the material changes. This change results in the production of new substances and the generation of energy. As a fuel is burned, some of it is actually consumed. The Law of Conservation of Mass tells us that any mass lost converts to energy. In the case of fire, this energy is in the form of light and heat. Burning also results in the generation of airborne fire gases, particles, and liquids.

5.8.1 Smoke

Smoke is a visible product of incomplete combustion. Smoke ordinarily encountered during a fire consists of a mixture of oxygen, nitrogen, carbon dioxide, carbon monoxide, finely divided particles of soot and carbon, and a miscellaneous assortment of products which have been released from the material involved. In an underground fire, as smoke increases and visibility is reduced, the lack of visibility causes disorientation, which can trap persons in the mine. Smoke inhalation is the primary hazard to people who have no respiratory protection in a fire situation.

5.8.2 Flame

Flame is the visible luminous body of a burning gas, which becomes hotter and less luminous when it is mixed with increased amounts of oxygen. This can be demonstrated when one can observe the luminous flame of a newly lit cutting torch and comparing it to a cutting torch that has been enhanced with oxygen to produce an almost invisible flame capable of cutting metal. This loss of luminosity is due to a more complete combustion of carbon. For this reason, flame is considered to be a product of combustion. However, heat, smoke, and gas can develop in certain types of smoldering fires without evidence of flame.

5.9 Factors Contributing To Industrial Fires

To eliminate the causes of fire, it is important to first determine the many ways in which fire can start. Some common causes of industrial fires are listed below:

5.9.1 Electrical Equipment

Electrical equipment should be installed and maintained in accordance with appropriate codes and standards.

Temporary or makeshift wiring, particularly if defective or overloaded, should never be used.

Portable electrical tools and extension cords should be inspected frequently.

Use waterproof cords and sockets in damp places and use explosion-proof fixtures and lamps in the presence of highly flammable gases and vapors.

Always use grounded or double-insulated electrical equipment, especially portable electrical tools.

Use switches, lamps, cords, fixtures, and other electrical equipment listed by a recognized testing and certifying agency.

Ensure employees are instructed in the correct use of electrical equipment.

Prohibit employees from tampering with equipment, blocking circuit breakers, using wrong fuses, bypassing fuses and installing equipment without authorization.

Ensure electrical installations and all electrical equipment are checked periodically.

5.9.2 Smoking

Ensure smoking materials are used only in designated areas and they are completely extinguished before discarding.

Prohibit smoking in hazardous areas.

5.9.3 Friction

Excessive heat generated by friction causes a very high percentage of industrial fires.

Develop preventive maintenance programs to monitor plant machinery and make frequent inspections to see bearings and other contact surfaces are kept well maintained and do not run hot. Installation of heat sensors and sprinkler systems at machine friction points though not preventative will alert your to trouble and help reduce losses.

Keep the accumulation of flammable dust or material on or near equipment to a minimum.

Take every precaution to keep foreign objects from entering machines or processes.

5.9.4 Open Flames

Heating equipment, torches, welding and cutting operations are principal offenders.

Establish policies and procedures for open flames, cutting and welding and hot work.

Ensure the policies are adhered to.

Monitor fumes and emissions in all confined spaces.

5.9.5 Spontaneous Ignition

Spontaneous ignition results from a chemical reaction in which there is a slow generation of heat from oxidation of organic compounds that, under certain conditions, is accelerated until the ignition temperature of the fuel is reached. This condition is reached only where there is enough air for oxidation but not enough ventilation to carry away the heat as fast as it is generated.

5.9.6 Housekeeping

Poor housekeeping is another factor that contributes to industrial fires. Properly collecting and storing combustibles and disposing of rubbish will

prevent fire hazards.

Ensure bulk materials are stored in well ventilated areas and do not accumulate in the mine.

5.10 Fire Control & Extinguishing Methods

Under the theory of the fire tetrahedron, there are four methods of fire suppression:

(1) Remove the fuel,

(2) Reduce or eliminate the supply of oxygen,

(3) Reduce the temperature,

(4) Stop the chain reaction.

The method of stopping a rapid chemical reaction (burning) depends upon the size and the type of fuel involved. In order to select the proper type of fire extinguisher, it is necessary to know how fires may be extinguished.

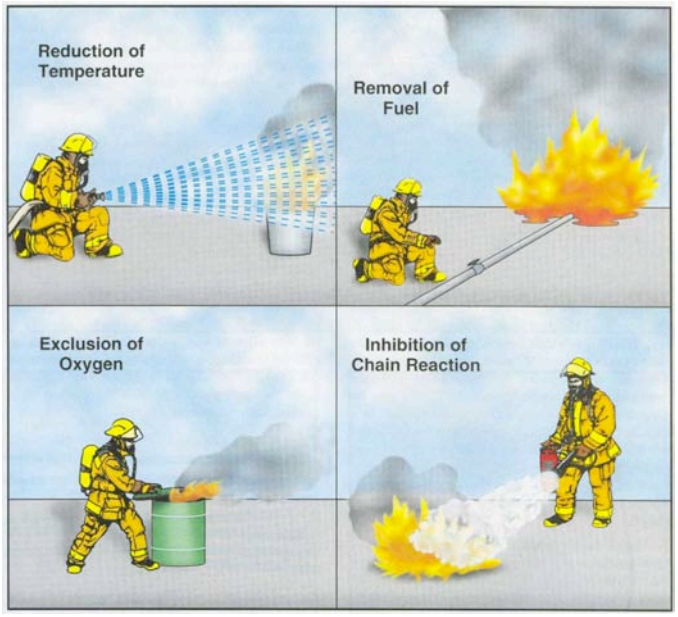

Figure 5.19 - Four Methods Of Fire Extinguishment.

5.10.1 Removal Of Fuel

The removal of fuel to extinguish fire is effective, but not always practical or possible. For example, methods of fuel removal include turning off the fuel supply, pumping flammable liquids from a burning tank or removing unburned portions of large piles of solid combustible materials such as that found in silos or coal piles. The removal of fuel can also be accomplished by diluting liquid material that is burning. Water will dilute materials, which are soluble in water, such as alcohol. Flammable liquids that are not soluble in water can be diluted with an “emulsifying” agent that mixes with the top layer of the flammable liquid to stop vaporization. Foam and other surface-active agents can contain flammable vapours and so remove fuel from combustion areas. Flammable gases can also be diluted and become non-combustible with the addition of an inert gas such as carbon dioxide or nitrogen.

5.10.2 Reduce Or Eliminate The Supply Of Oxygen

The process of “smothering” or “blanketing” will extinguish fires by separating the oxygen from the other essentials that make a fire. An example of this method is extinguishing an oil fire in a cooking pan by placing the cover on the pan. Smothering is generally an easy method of extinguishing. In some cases, however, fires cannot be extinguished by smothering. For example, some plastics, such as cellulose nitrate, and some metals, such as titanium, cannot be extinguished by smothering because they do not depend on external air supply. In these cases, a special method of extinguishing or control is required.

5.10.3 Reduction Of Temperature

One widely used method of fire extinguishing is cooling or quenching. Temperature control involves the absorption of heat with a resultant cooling of the fuel to a point at which it ceases to release enough vapours to maintain a flammable gas. Heat is carried away from a fire by radiation, conduction, and convection, as well as absorption by a cooling agent. Of all the extinguishing agents, water is the most commonly used.

5.10.4 Prevention Of Chain Reaction

This last method of extinguishing a fire is to prevent the chain reaction that occurs during the combustion process. Basically stated, scientists have found that the simultaneous formation and consumption of certain atoms is the key to the chain reaction, which produces the flame. Certain chemical substances have the ability to break up this reaction. When introduced into the fire in the proper amounts, the flame cannot continue to burn and the fire is extinguished. Examples of these chemical substances would be dry chemical extinguishers or halon type extinguishers. Dry chemical extinguishers work well on a liquid type fire but may not work well where there are smouldering remains.

5.11 Fire Fighting

In order to fight a fire effectively three basic principles apply:

(1) **LOCATE** the fire. You can't do much about putting it out until you know where it is.

(2) **CONFINE** the fire. Don't let the fire spread and become more serious.

(3) **EXTINGUISH** the fire.

When attempting to **locate** a fire it is important not to put yourself or others in danger. When a fire is not easily pinpointed it is best to evacuate the area until you are able to access the area in a proper manner.

A fire can be **confined** by:

1. Removing nearby combustibles,
2. Wetting down nearby combustibles,
3. Cutting off the oxygen supply to the fire.

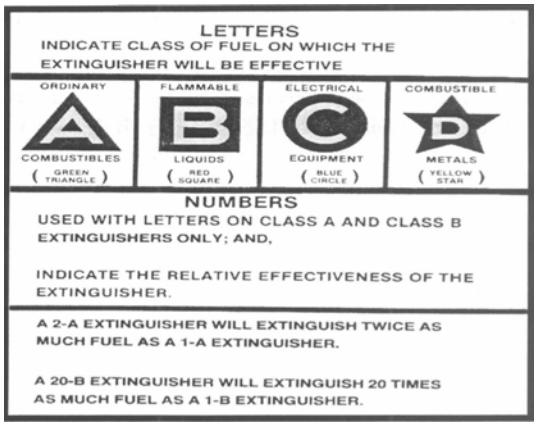

Figure 5.20 – Classes of fires.

A fire can be **extinguished** by:

1. The **Direct** Method, by applying an extinguishing agent directly on the fire.
2. The **Indirect** Method, by controlling the environment in which the fire is burning. This method is used when a fire has reached such proportions that the Direct Method cannot be used due to heat, etc.

5.12 Classification Of Fires And Extinguishing Methods

5.12.1 Class “A” Fires

Fires involving ordinary combustible materials, such as wood, cloth, paper, rubber and many plastics.

Extinguishing Method - Water is normally used for its cooling or quenching effect to reduce the temperature of the burning material below its ignition temperature.

5.12.2 Class “B” Fires

Fires involving flammable liquids, greases and gases.

Extinguishing Method - The smothering or blanketing effect of oxygen exclusion is most effective. Other extinguishing methods include removal of fuel and temperature reduction.

5.12.3 Class "C" Fires

Fires involving energized electrical equipment.

Extinguishing Method - This type of fire can sometimes be controlled by a non-conducting extinguishing agent. The safest procedure is always to attempt to de-energise high voltage circuits and treat as a Class "A" or "B" fire depending upon the fuel involved.

5.12.4 Class "D" Fires

Fire involving combustible metals, such as magnesium, titanium, zirconium, sodium and potassium.

Extinguishing Method - The extremely high temperature of some burning metals make water and other common extinguishing agents ineffective. There is no agent available that will effectively control fires in all combustible metals. Special extinguishing agents are available for control of fire in each of the metals and are marked specifically for that metal.

5.13 Portable Fire Extinguishers

Equipment used to extinguish and control fires is of two types: fixed and portable. Fixed systems include water equipment, such as automatic sprinklers, hydrants and standpipe hoses, and special pipe systems for dry chemicals, CO_2, Halon, and foam. Fixed systems, however, must be supplemented by portable fire extinguishers. Using a portable extinguisher on a fire in the early stage may prevent the fire from spreading. Because the fire is out in this early stage there may not be enough heat or smoke to discharge a fixed extinguishing system.

INSTRUCTIONS:
1. REMOVE NOZZLE, PUSH PUNCTURE LEVER DOWN.
2. START BACK 12 FEET, AIM AT BASE OF FIRE.
3. SQUEEZE NOZZLE, SWEEP SIDE TO SIDE.
ANSUL
RED LINE
Figure 5.21 – Ansul instructions & usable on fire classes A B C.

Principles Of Use

To be effective, portable extinguishers must be:

- Approved by a recognized testing laboratory.
- The right type for each class of fire that may occur in the area.
- In sufficient quantity and size to protect against the expected exposure in the area.
- Located where they are easy to reach for immediate use.
- Maintained in operating condition, inspected frequently, checked against tampering, and recharged as required.
- Operable by area personnel, who are trained to use them effectively and promptly.

5.14 Basic Steps For Fire Extinguisher Use

Portable extinguishers come in many sizes and types. While the operating procedures of each type of extinguisher are similar, the person using the extinguisher should be knowledgeable about the detailed instructions found on the label of the extinguisher before using it.

Key points for effective extinguisher use:

- Quickly check the extinguisher before attempting to use it,
- Pressurize or prepare the extinguisher before approaching the fire,
- Approach the fire from the upwind side (wind at your back),
- Point the nozzle at the base of the fire,
- Discharge the extinguisher with a rapid sweeping motion, ensuring the extinguishing agent reaches the base of the fire,
- Advance slowly to achieve final extinguishment,

P – Pull the pin

A – Aim the nozzle at the base of the fire

S – Squeeze the trigger while holding extinguisher upright

S – Sweep side to side covering area of fire

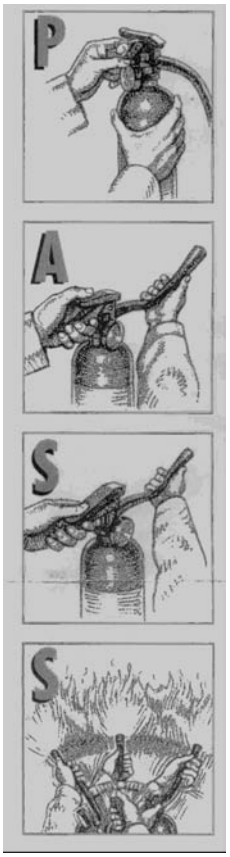

Figure 5.22 – ABC Fire Extinguisher – Contained Pressure Type Instructions

- Do not chase the fire ball,
- Ensure the fire is out,
- Do not turn your back on a fire,
- If the fire extinguisher does not put the fire out, sound the general alarm.

5.15 Classification Of Fire Extinguishers

Portable extinguishers are classified to indicate their ability to handle specific classes and sizes of fires. This classification is necessary because new and improved extinguishing agents and devices are constantly being developed and because of the variety of sizes of extinguishers available. Labels on extinguishers indicate the class and relative size of fire that they can be expected to handle.

Portable fire extinguishers are classified according to their intended use. Each portable extinguisher is rated for type of fire and its fire fighting capabilities.

The rating system is based on physical tests conducted by the Underwriter's Laboratories, Inc. and the Underwriter's Laboratories of Canada. Tests are designed to determine the extinguishing potential for each size and type of extinguisher.

The ratings, which are identified by a numeral and a letter, define the extinguishing potential of an extinguisher. The letter refers to the class of fire on which the extinguishing agent is most effective. The number, used in conjunction with Class A and B extinguishers only, indicates the relative effectiveness of the extinguisher. Multiple letters or number-letter ratings are used on extinguishers, which are effective on more than one class of fire.

For example, a 4A: 10 B: C rating signifies that the extinguisher is recommended for both Class A and Class B fires and is safe to use if the fire is near or at energized equipment.

The size of extinguisher to be installed in an area should be able to protect the size of area or equipment that it is being installed on.

Figure 5.23 – Common fire extinguishers (L to R) 5 lb. dry chemical, 20 lb. dry chemical, 30 lb. mobile equipment fire suppression dry chemical container.

Example 1 - Dry Chemical Extinguisher, Rated 5 - B, C:

This extinguisher should extinguish approximately five times as much Class B fire as a 1-B unit and should successfully extinguish a flammable liquid fire of 5 square foot area. It is also safe to use on fires involving energized electrical equipment.

Example 2 - Multi-Purpose Extinguisher, Rated 4- A, 20 - B, C:

This extinguisher should extinguish approximately four times as much Class A fire as a 1-A extinguisher, 20 times as much Class B fire as a 1-B extinguisher, and a flammable liquid fire of 20 square foot area. It is also safe to use on fires involving energized electrical equipment.

Multiple Markings

Extinguishers suitable for more than one class of fire should be identified by multiples of symbols previously mentioned.

Portable fire extinguishers, although very effective at preventing a small fire from spreading, are not intended to be a substitute for sprinkler systems, fire suppression systems, hose streams, or other fire fighting devices. They are, however, considered necessary even though a mine site may be equipped with automatic fire protection devices.

5.16 Low And High Expansion Foam

By definition, fire-fighting foam is an aggregate of gas filled bubbles formed in a water solution. It can be described as: “a fluid aqueous suspension of air or gas, in the form of small bubbles separated by films of solution”.

There are two types of foam-generation methods:

(1) Mechanical or air generated and

(2) Chemical generated.

Fig 5.24 – Turbex Mark II High Expansion Foam Generator

Mechanical or Air Generated Foams consist of bubbles of air produced when air and water are agitated with a foam producing agent.

Chemical Foam is formed by a chemical reaction in which masses of bubbles of CO_2 gas and a foaming agent produce an expanded froth.

5.16.1 How Foam Works

Foams fight combustible liquids in the following four ways:

1. Excludes air from the flammable vapors.
2. Eliminates vapor release from the fuel surface.
3. Separates flames from the fuel surface.
4. Cools and absorbs heat from fuel and metal surface.

In this application, it can be said that foams actually remove three components of the fire tetrahedron, heat, fuel and oxygen, by separating each component, thus making the fourth irrelevant.

5.16.2 Characteristics Of Foam

Six features characterize good mechanical foam.

It must:

a) Flow freely, to cover a surface rapidly.

b) Be cohesive enough to form a vapor-tight blanket and have high adhesion properties.

Figure 5.25 – Types of foam used in fire fighting. (L to R) 6% foam – is used up quickly, 2 types of 3% foam – most commonly used foam, Pyrocool foam – 0.4% - used in compressed air foam systems.

c) Be resistant to heat.

d) Resist breakdown by the flammable liquids, vapors and combustion products involved.

e) Retain water to provide a lasting seal.

f) Be light enough to float on low gravity liquids, but heavy enough to resist disruption air movement.

These characteristics will be affected by the type and quality of the foam liquid, the efficiency of the foam making equipment, and the temperature and pressure of water used.

(***Note:*** *If travel through foam [AFFF] must be done by members of a Mine Rescue team all members must travel through the foam using SCBA's. Another important note is if travel must be done through foam, all equipment and wearing apparel must be thoroughly washed once mission is completed.*)

5.17 Site Specific Fire Procedures

All Manitoba mine sites have conditions, processes and circumstances where the potential fire hazards exist. It is incumbent upon each mine site to identify those hazards and establish prevention and response procedures to deal with them. Prevention and response procedure should be contained in the company emergency response manual. Where the procedures require mine rescue involvement, mine rescue personnel must be adequately trained to respond to these hazards in an appropriate manner. Site specific prevention and response procedures should be included in an appendix of the Corporate Emergency Procedures manual.

5.18 Sealing Mine Fires

5.18.1 Purpose Of Seals

Seals have three basic purposes:

1. Control or change ventilation patterns.
2. Confine fires and minimize mine contamination.
3. Provide a safe refuge for men trapped underground.

5.18.2 Types Of Seals *(see Section 4.5 and 4.6 for additional information)*

Permanent seals are usually constructed of concrete, bricks or cinder blocks.

Temporary seals can be made of any available material, which will permit quick construction and can be used to achieve the above noted basic principles of seal construction.

The three most common types of temporary seals include:-

1. Brattice cloth, fabrine or heavy gauge plastic with or without a wooden frame.
2. Sandbags.
3. Lumber, boards or other appropriate material.

5.18.3 Sealing A Mine Fire

Sealing a mine fire should be considered a last resort and should not be attempted until all other methods of extinguishing have been exhausted. The

decision to seal a fire should be by the Director of Operations in conjunction with Incident Command Centre.

In order to confine a mine fire it is best if seals can be constructed on the intake and the exhaust sides of the fire simultaneously. However, if this is not possible, the seal on the intake side should be erected first. Seals should be constructed as close to the fire as safety permits so the amount of air trapped behind the seals is kept to a minimum thereby smothering the fire in a much shorter time. If it proves absolutely necessary to seal the exhaust side first there are additional hazards associated with reduced visibility, heat, explosive gases and toxic atmospheres.

When seals are being constructed they should be back far enough (1,000 ft. / 300 m. when practical). This is to protect the team members working on them as well as the seals from being damaged or dislodged should there be an explosion.

Temporary seals are usually constructed prior to installing a permanent seal, for two basic reasons;

(1) Construction is simpler and less labour intensive.
(2) If an explosion destroys a temporary seal, it is easier to replace.

Due to the possibility of an explosion, permanent seals should not be constructed until it is safe to do so.

Upon completion of the installation of either a temporary or permanent seal, all personnel should be removed from the sealed area as quickly as possible and stay away from the area for at least 24 hours. This requirement may be overlooked if there is a remote gas sampling process to determine environmental conditions behind the seal.

If a major fire underground is sealed, Mine Rescue Teams should be withdrawn from the mine for a minimum of 24 hours so that they will not be exposed to the danger of an explosion, due to gas build-up behind seals.

5.18.4 Fire / Safety & Back-up Seals

Prior to entering an area where a seal has been erected, it may be necessary to erect a fire/safety or back-up seal in the immediate vicinity. Factors to

consider when erecting seals include:

(1) The quality of the atmosphere outside the seal. Mine rescue teams must minimize the amount of toxic gas introduced into the area behind the seal and not increase the risk to personnel who have taken refuge behind the seal.

(2) In the situation where a fire seal exists, mine rescue teams must take precautions to prevent the introduction of oxygen into the fire area. If a sufficient volume of oxygen rich air enters a fire area, the fire may re-start or an explosion may occur.

Underground fires can travel faster against the ventilation airflow than with the ventilation. This is because fire depletes oxygen from the immediate area and must draw oxygen from incoming air to sustain burning.

5.19 Mine Recovery

After a mine emergency involving a fire or other event stops or reduces production, it is important to get the mine back to normal as conditions permit.

Depending on the circumstances and the extent of damage, recovery operations can range from a few days work to re-establish ventilation in a small area of a mine to weeks or months of significant rehabilitation work.

During the rehabilitation phase, mine rescue teams may or may not be involved. It is important to remember when mine rescue teams are involved in rehabilitation work they must keep the fundamental principles of mine rescue in sight;

(1) Ensure the safety of the mine rescue team and its members.

(2) Take the necessary steps to safeguard mine personnel who may be at risk *(this may be mine rescue team members).*

(3) Protect the mine property from further damage.

(4) Rehabilitate the mine.

Until an area of the mine resumes production, mine rescue teams using breathing apparatus may be required to monitor conditions, rebuild bulkheads, and where necessary, clear debris and stabilize ground conditions.

Once the area has been ventilated and deemed safe to work in, regular mine personnel can take over the rehabilitation work.

5.20 Re-establishing Ventilation After A Fire Or Explosion

Re-establishing ventilation and bringing fresh air to an area of the mine damaged by fire or explosion may be a primary task of mine rescue teams in a recovery operation. Once this is done, regular work crews can help with the recovery effort.

In an area sealed due to a fire or explosion, the task of resuming normal operations becomes more difficult. The area must first be deemed safe to unseal, followed by damage assessment and the repair or rebuilding of the ventilation system.

If the area has not been sealed, the job of re-establishing ventilation is a little easier. It involves assessing the damage and making the necessary repairs to re-establish normal ventilation.

In most instances after an explosion there is a great deal of construction and rehabilitation work required. Mine rescue Teams must be keenly aware of the dangers that may be present in an area damaged by fire or explosion.

5.21 Unsealing A Fire Area

Unsealing a fire area requires careful planning, usually by senior management and only after a detailed analysis of all risk factors associated with the affected area. Opening seals prematurely could cause a re-ignition of the fire and, in mines with explosive gases, an explosion. When conducting gas analysis behind a seal the more common types of gases tested for are oxygen, carbon dioxide, carbon monoxide, methane, hydrogen, and nitrogen.

While mine rescue team members do not plan the unsealing operation, it is important for them to understand the risk factors associated with work in these areas.

Prior to unsealing a fire a number of factors should be considered. The following is a check list of some of the more obvious considerations,

- The persons responsible for making the decision to unseal must exercise sound judgement at all times,
- There must be confirmation the fire has been extinguished,
- Breathing apparatus must be worn.
- An accurate assessment of the atmosphere behind the seal must be

obtained,

- The effect of the unsealing process should be predictable,
- The extent and intensity of the fire should be known,
- The characteristics of the burning material, rock type and materials involved,
- The tightness or quality of the seals should be known,
- The pressure differential on both sides of the seal should be known,
- The temperature in the sealed area may be relevant,
- The location of the fire area with respect to ventilation is important,

What is imperative about unsealing an area where a fire or explosion has occurred is to expect the unexpected and to take all necessary precautions to minimize the chance of re-ignition or placing personnel at unnecessary risk.

5.22 Review Questions

1) What are the four elements that form the fire tetrahedron?

2) When is an atmosphere considered Oxygen enriched?

3) What does it mean to be below LEL?

4) What does it mean to be above the UEL?

5) What is the action called when fuel gases are evolved from solid fuels through the action of heat? Give an example.

6) What are the five stages of fire development?

7) Name six most common causes of industrial fires.

8) Describe the four methods of extinguishing a fire.

9) What three principles apply to effectively fight a fire?

10) Briefly describe the A, B, C& D classes of fires.

11) List 10 key points for using a portable fire extinguisher?

12) What four ways does foam, extinguish class B fires?

13) What purposes are seals / stoppings erected in a mine?

14) What is the object of sealing a mine fire?

15) When should you decide to seal a fire area or mine access?

16) What distance should seals be from a fire?

17) Should temporary fire seals be erected first? If yes, explain why.

18) During mine recovery, the four fundamental principles of mine rescue work must be followed. List them.

19) On what authority should a fire seal be opened?

20) After a fire has been sealed, then reopened, what procedures should be followed?

21) Prior to unsealing a fire a number of factors should be considered. List nine.

LEARNING OBJECTIVES AND TARGET AUDIENCE

SECTION 6
SUBSTANCES IN THE WORK ENVIRONMENT

Learning Objectives

Section 6 provides information about hazardous substances in the work environment and how they relate to mine personnel during normal mining activities and during a mine fire or other emergency.

Suggested Target Audience

Section Number	Topic	Basic Mine Rescue Trainees	Standard Mine Rescue Trainees	Advanced Mine Rescue Trainees	Mine Rescue Equipment Technicians	Mine Rescue Instructors	Director Of Operations & Resource Personnel	Senior Management Personnel	Supervisors	New Or Transferred Employees
6.1	Threshold Limit Values	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
6.2	Threshold Limit Value Categories	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
6.3	TLV's Of Chemical Contaminants	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
6.4	Gases Produced From Mine Fires	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
6.5	Combined Threshold Limit Values (TLV's)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
6.6	Review Questions	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Section 6. SUBSTANCES IN THE WORK ENVIRONMENT

The air breathed in the mine atmosphere contains dust, smoke, fumes, vapours and gases created by activities in the mine environment. In most cases, the human body is able to cope with small quantities of these substances, however, there are times when the substances in mine air are excessive and have the potential to cause harm.

A mine atmosphere may place people at unacceptable risk if concentrations of contaminants affect personnel directly or indirectly by displacing oxygen, poisoning, or burning / exploding.

It is important for emergency response personnel to understand the relationship between substances found in the mine environment and the effect on mine personnel.

6.1 Threshold Limit Values

Threshold Limit Values (TLV's) refer to airborne concentrations of substances and represent the upper limits of conditions under which it is believed nearly all workers may be repeatedly exposed day after day without adverse effects.

Due to the wide variation in individual susceptibility, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit and a smaller percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness.

Contamination by a gas is generally measured in parts per million (ppm) or in a percentage (%) of normal air (1% is equal to 10,000 ppm).

TLV’s are based on available information from industrial experience and from experimental human and animal studies, and when possible, a combination of the three. The basis on which these values are established may differ from substance to substance. The precision of the estimated TLV is also subject to variation. The most current information available should be consulted in order to assess the effects of an identified substance.

6.2 Threshold Limit Value Categories

6.2.1 Threshold Limit Value - Time Weighted Average (TLV-TWA)

TLV-TWA is the time-weighted average concentration for a conventional eight (8) hour work day and a 40 hour work week, to which it is believed nearly all workers may be repeatedly exposed, day after day, for a working lifetime without adverse effect.

6.2.2 Threshold Limit Value - Short Term Exposure Limit (TLV-STEL)

TLV-STEL is the concentration to which it is believed workers can be exposed continuously for a short period of time without suffering from (1) Irritation, (2) chronic or irreversible tissue damage, or (3) narcosis (substance induced stupor) of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, and provided the daily TLV is not exceeded. It is not a separate independent exposure limit; rather it supplements the time weighted average (TWA) limit where there are recognized acute (coming to a crisis quickly) effects from a substance whose toxic effects are primarily of a chronic nature. STEL's are recommended only where toxic effects have been reported from high short-term exposures in either humans or animals.

STEL is defined as a 15 minute TWA exposure which should not be exceeded at any time during a **work day** even if the 8-hour TWA is within the TLV. Exposures above the TLV up to the STEL should not be longer than 15 minutes and should not occur more than four times per day. There should be at least 60 minutes between successive exposures in this range.

6.2.3 Threshold Limit Value - Ceiling (TLV-C)

TLV-C is the concentration that should not be exceeded during any part of the working exposure.

6.2.4 Immediately Dangerous To Life Or Health - (IDLH)

IDLH is a condition posing an Immediate Danger to Life or Health or a condition posing an immediate threat of severe exposure to contaminants such as radioactive materials which are likely to have adverse cumulative or delayed effects on health. Mine rescue personnel must be aware of the immediate or long term effects of exposing themselves or other people to concentrations of a contaminant present in an IDLH concentration. If a concentration of a contaminant is above the IDLH, only highly reliable breathing apparatus, such as an O_2 producing self rescuer or similar apparatus should be used to enter such an atmosphere or to move someone through that atmosphere.

When the exact concentration of a contaminant is undetermined or when it exists but the exact nature of the contaminant is unknown, mine rescue teams must assume an IDLH atmosphere and act accordingly.

When assessing exposure levels to a chemical contaminant, it is important to understand more than one contaminant may be present in the air at the same time. If this is the case, the combined exposure levels of all contaminants must be considered.

6.3 TLV's Of Chemical Contaminants

Included on the following page are some of the substances that may be present in the underground mine environment. While some of the listed gases are flammable or explosive and pose a serious concern, a more immediate concern may be due to their toxicity. An additional concern may be due to a substances ability to displace normal air and cause oxygen deficiency.

For additional information on chemical substances, physical agents and biological exposure indices please refer to the most recent addition of the American Conference of Government Industrial Hygienists (ACGIH) publication on TLV's (Threshold Limit Values) and BEI's (Biological Exposure Indices) or other recognized reference source.

Threshold Limit Values (TLVs)

Common Substances Which May Be Present In Mine Air

Substance ..... [CAS #]	**TLV ppm**	**STEL-C ppm**
Ammonia - NH_3 .....[7664-41-7]	25 ppm	35 ppm
Carbon Dioxide – CO_2 .....[124-38-9]	5,000 ppm	30,000 ppm
Carbon Monoxide - CO .....[630-08-0]	25 ppm	---
Chlorine - Cl_2.....[7782-50-5]	0.5 ppm	1 ppm
Hydrogen Sulphide - H_2S.[7783-06-4]	1 ppm	5 ppm
Nitrogen Dioxide - NO_2 ..[10102-44-0]	3 ppm	5 ppm
Sulphur Dioxide - SO_2.....[7446-09-5]		0.25 ppm

TLV & STEL values taken from the 2011 TLV's for Chemical Substances and Physical Agents & Biological Exposure Indices of ACGIH Worldwide.

CAS # is a number uniquely assigned to a chemical by the Chemical Abstract Services and is recognized worldwide in any language.

Other Substances Which May Be Present In Mine Air

SUBSTANCE..... [CAS #.]	TLV ppm	STEL-C ppm
Acetaldehyde - C_2H_4O .....[75-07-0]	---	25 ppm (Ceiling)
Acrolein - CH_2CHCHO .....[107-02-8]	---	0.1 ppm (Ceiling)
Aniline - $C_6H_5NH_2$.....[62-53-3]	2 ppm	---
Benzene - C_6H_6.....[71-43-2]	0.5 ppm	2.5 ppm
Carbon Disulphide - CS_2.....[75-15-0]	1 ppm	---
Ethyl Mercaptan - C_2H_5SH...[75-08-1]	0.5 ppm	---
Formaldehyde - CH_2O .....[50-00-0]	---	0.3 ppm (Ceiling)
Formic Acid - HCCOOH.....[64-18-6]	5 ppm	10 ppm
Hydrogen Chloride - HCL [7647-01-0]	---	2 ppm (Ceiling)
Methyl Chloride - CH_2Cl_2O...[74-87-3]	50 ppm	100 ppm
Phenol - C_6H_5OH .....[108-95-2]	5 ppm	---
Toluene - $C_6H_5CH_3$ .....[108-88-3]	20 ppm	---
Vinyl Chloride - CH_2CHCL ...[75-01-4]	1 ppm	---

TLV & STEL values taken from the 2011 TLV's for Chemical Substances and Physical Agents & Biological Exposure Indices of ACGIH Worldwide.

CAS # is a number uniquely assigned to a chemical by the Chemical Abstract Services and is recognized worldwide in any language.

6.4 Gases Produced From Mine Fires

When mine fires occur, they produce noxious gases contaminating sections of the mine affected by the fire. Many of the gases are very dangerous and can cause short and long term health problems. The following chart illustrates some common combustible materials found in mines and the gases produced when these materials burn.

Gases Produced From Burning Material

Material	Gases Produced
Neoprene conveyor belts	HCl, CO, CO_2, SO_2, H_2, Benzene & Formic Acid
Polyvinyl chloride (PVC) conveyor belts, PVC pipe	HCl, CO, CO_2, Vinyl Chloride, Benzyl Chloride, Benzene, Toluene, Phenol
Polystyrene-butadiene conveyor belts	HCl, CO, CO_2, H_2S, CS_2, Methyl Chloride
Urethane foams	HCl, CO, CO_2, Aniline, Chloroethanol.
Wood (treated and untreated)	CO, CO_2, Acrolein, Formaldehyde, Acetaldehyde, HCN, Formic Acid.

6.5 Combined Threshold Limit Values (TLVs)

In an underground mine normal air can be changed quite drastically by its passage through a work environment. The day-to-day operations of the mine cause the air to become contaminated with a variety of toxic gases. Those contaminants, which are toxic, have an established TLV.

While the TLV's establish the concentration of each gas which is acceptable over an 8 hour period, 40 hour week without adverse effects. The air in a mine may contain a combination of different gases which, when combined may cause adverse effects on a worker and therefore must be taken into account.

An example atmosphere may have the following gas readings:

Carbon Monoxide (CO)	15 ppm	TLV = 25 ppm
Oxide of Nitrogen (NO_2)	1 ppm	TLV = 3 ppm
Sulphur Dioxide (SO_2)	1 ppm	TLV = 2 ppm

None of the readings are over the safe limits, however the combined TLV's must be taken into consideration.

These readings can be expressed as fractions, and when combined or added together must not exceed 1.

From the readings above the following example is calculated:

$$CO\ 15/25 + NO_2\ 1/3 + SO_2\ 1/2 = 180/300 + 100/300 + 150/300 = 430/300 = 43/30 = \mathbf{1.43}$$

From this example you can see the combined TLV exceeds 1 and a worker exposed to the combined gases could suffer ill effects.

It must be remembered not only could these gases cause problems by breathing them, they could begin to displace the oxygen causing further problems to those exposed to the atmosphere in the area.

6.6 Review Questions

1) Describe how harmful gases affect people?

2) What is an inert gas?

3) What is a dangerous atmosphere?

4) Under what circumstances can an inert gas be dangerous?

5) How would you convert a percentage (%) gas to parts per million (ppm)?

6) Explain what TLV means?

7) Explain what TLV-STEL means?

8) Explain what TLV-C means?

9) When a mine rescue team enters an atmosphere with unknown contaminants what should they consider the atmosphere to be? Explain.

10) Given the following gas readings, what material is likely burning?

    a) CO, CO_2, Formaldehyde -

    b) HCl, CO, CO_2, H_2S, CS_2 -

    c) HCl, CO, CO_2, Chloroethanol -

    d) HCl, CO, CO_2, SO_2, H_2 -

11) Calculate the combined TLV of smoke containing 20 ppm - CO, 3ppm - H_2S?

LEARNING OBJECTIVES AND TARGET AUDIENCE

SECTION 7
MINE AIR

Learning Objectives

Section 7 provides information about the properties of mine gases, how these gases affect the mine environment and their effect on humans.

Suggested Target Audience

Section Number	Topic	Basic Mine Rescue Trainees	Standard Mine Rescue Trainees	Advanced Mine Rescue Trainees	Mine Rescue Equipment Technicians	Mine Rescue Instructors	Director Of Operations & Resource Personnel	Senior Management Personnel	Supervisors	New Or Transferred Employees
7.1	Introduction To Mine Air	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
7.2	Composition Of Air	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
7.3	The Mechanics Of Breathing	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
7.4	General Information About Gases	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
7.5	Properties And Characteristics Of Specific Gases	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
7.6	Chart Of The Properties Of Gases	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
7.7	Gas Detection	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
7.8	Electronic Gas Monitor Cross Sensitivity / Interference	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
7.9	Charts Of Gas Detection	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
7.10	Review Questions	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Section 7. MINE AIR

7.1 Introduction To Mine Air

In underground mines, air is introduced into the mine environment by powerful ventilation systems directing fresh air to the various areas of the mine and ultimately return the air to surface via exhaust systems. During normal operations, mine air may contain a variety of contaminants such as gas, dust, smoke and fumes. In most cases, the level of contaminants are minimal and are controlled at levels specified by law or by a mine's operating standards. Effective ventilation systems are critical to the operation of an underground mine.

The air in a well-ventilated mine seldom shows any depletion of the oxygen content. There are however times when the air in the mine environment is compromised by fire, explosion or other conditions depleting or displacing oxygen. When such an event occurs emergency response procedures are often required to rectify the situation. Mine rescue personnel are often part of an emergency response. They must ensure their action or inaction does not endanger themselves or others, causing an emergency situation to become more serious. In order to effectively respond to an emergency, mine rescue personnel must have knowledge about air contaminants and an understanding of how to effectively manage them. An important factor in managing air contaminants is to understand their characteristics, physical properties and the effect they may have on people.

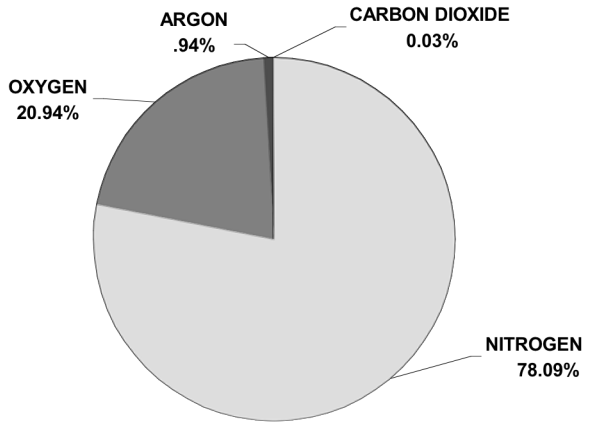

Figure 7.1 – A chart showing the components of normal air.

7.2 Composition Of Air

Air is a physical mixture of a variety of individual gases, a transparent medium that forms the earth's atmosphere. Air is normally invisible, however it can be weighed, compressed to a liquid, or frozen to a solid. Pure dry air is a mixture of gases in relatively stable proportions: nitrogen, oxygen, argon and carbon dioxide by volume, plus trace amounts of other gases such as hydrogen, ozone and nitrogen oxides.

Primary Components Of Air

Gas	% By Volume Concentration	Concentration In PPM
Nitrogen	Approximately 78% (78.09%)	N/A
Oxygen	Approximately 21% (20.94%)	N/A
Argon	Approximately 1% (0.94%)	N/A
Carbon Dioxide	0.03%	N/A

Other Gases Commonly Found In Air

Gas	% By Volume Concentration	Concentration In PPM
Neon	N/A	18.0
Helium	N/A	5.2
Methane	N/A	2.2
Krypton	N/A	1.0
Nitrous Oxide	N/A	1.0
Hydrogen	N/A	0.5
Xenon	N/A	0.08

7.3 The Mechanics Of Breathing

Breathing or respiration is essential to life for humans. The fresh air we breathe contains approximately 21% oxygen. The respiratory system is used to draw air into the lungs and release unused oxygen and carbon dioxide back into the air. In the lungs, blood absorbs some of the oxygen and collects carbon dioxide as a waste product. When we exhale, we release carbon dioxide and approximately 16% oxygen.

The respiratory system has three main parts: the airway, the lungs and the diaphragm. The airway is the passage which air follows to get from the nose and mouth to the lungs. In the lungs, blood drops off carbon dioxide and picks up oxygen. This process is called gas exchange. The diaphragm is a smooth, flat muscle located below the lungs used to facilitate the breathing process.

The respiratory centre in the base of the brain controls breathing. The respiratory centre monitors the amount of oxygen and carbon dioxide in the blood. As the levels of oxygen get lower and the carbon dioxide levels increase, the respiratory centre responds by changing the rate and depth of breathing.

How much oxygen is used and how much carbon dioxide is given off, is related to the level of physical activity. As physical activity increases, your heart rate also increases to compensate for the demand for more oxygen. Breathing slows down when less oxygen is required and as a result less carbon dioxide is expelled.

The lungs have no way of drawing air into themselves. Instead, the diaphragm and the muscles between the ribs work together to expand the chest, which in turn expands the lungs. This causes air to be pulled into the lungs. As the breathing muscles relax, the chest returns to its smaller size and air is forced out of the lungs.

7.3.1 Oxygen Consumption

The average person conducting a routine task while breathing normal air will consume approximately 20% of the oxygen they breathe into their lungs. This means their exhaled breath will contain approximately:

78% Nitrogen

16% Oxygen

4.5% Carbon Dioxide

Persons breathing pure oxygen will consume about 0.3 liters per minute while at rest. With moderate exercise this consumption increases to 0.9 liters per minute and heavy labour will increase consumption to 2.1 liters per minute.

Personnel taking refuge in a sealed environment will require approximately $1m^3$ (cubic meter) of air per person per hour in order to maintain normal breathing. It must be remembered people in the sealed area could suffer the effects of CO_2 poisoning if the area is not large enough to support the number of people in the area.

7.4 General Information About Gases

7.4.1 Colour, Odour, And Taste

Colour, odour, and taste are physical properties of substances that can help to identify a gas using our senses. Hydrogen sulphide, for example, has a distinctive "rotten egg" odour. Some gases may taste bitter or acidic; others sweet.

The odour of some blasting fumes, together with a light brownish colour, indicates there may be oxides of nitrogen present. Caution must be exercised when identifying a gas by colour, taste or odour because:

a) It may place a person at unnecessary risk,
b) Our senses are not accurate detection devices.

In order to accurately identify a single gas or combination of gases, appropriate sampling instruments and procedures must be used.

7.4.2 Solubility

Solubility is the ability of a gas to dissolve in a liquid. Solubility is an important factor to consider during recovery operations. When a mine is sealed off for a period of time, water can collect in pools and may dissolve oxygen, thus creating an oxygen deficient atmosphere. In other instances, gases such as sulphur dioxide or hydrogen sulphide may dissolve in water and be reintroduced into the air when the water is agitated by pumping or walking through it.

7.4.3 Specific Gravity

Specific gravity is the weight of a gas compared to an equal volume of air under the same temperature and pressure (Also referred to as "relative weight").

The specific gravity of air is 1.0. The weight of air acts as a reference point from which we measure the relative weight of other gases. For example, a gas that is heavier than air has a specific gravity higher than 1.0. A gas that is lighter than air will have a specific gravity less than 1.0. The specific gravity of a gas determines whether it will rise or fall. Gases with a specific gravity of more than 1.0 will fall (sulphur dioxide) and those with a specific gravity of less than 1.0 will rise (methane).

If the specific gravity of a gas is known, mine rescue personnel should know where it will be located in the mine and where to sample. Gases that are close to 1.0 (carbon monoxide) may be mixed with the general atmosphere and may not be concentrated in high or low places.

In addition to knowing where to look for a gas, specific gravity will also give an indication as to how quickly the gas will dissipate and how effectively it can be dispersed by ventilation.

Lighter gases, such as hydrogen, dissipate rapidly, so they are fairly easy to disperse. Heavier gases such as sulphur dioxide and carbon dioxide don't dissipate rapidly, so they're more difficult to disperse. It's much easier to remove a concentration of a light gas like hydrogen by ventilation than it is to remove the same concentration of a heavier gas like sulphur dioxide.

7.4.4 Explosive Range And Flammability

A gas that will burn is said to be "flammable". A flammable gas becomes explosive when the right combination of the gas, oxygen and an ignition source are present. The “explosive range” of a gas, is the upper and lower limits of the gas concentration that will permit an explosion to occur providing, there is also present, the necessary ratio of gas to oxygen mixture and an ignition source.

7.5 Properties And Characteristics Of Specific Gases

7.5.1 Oxygen (O_2)

Oxygen, a colourless, odourless, tasteless gas. Oxygen is essential for life. It does not burn but does support combustion.

Human health is directly proportional to the amount of oxygen present in the air breathed. Humans breathe normally and function best when the air contains approximately 21% oxygen, but can live and work at lower levels. When the oxygen content is about 17% humans will breathe a little faster and more deeply. The effect is about the same as traveling from sea level to an altitude of 5,000 feet. When breathing air containing as little as 15% oxygen, a person usually becomes dizzy, notices a buzzing in the ears, has a rapid heart beat, and will often suffer headaches. No one is free from these symptoms when the oxygen in the air falls to 10%. The flame of a safety lamp or candle is extinguished when the oxygen falls to about 16% (16.25%). It should be noted a minimum “safe level” has been established when the oxygen content in air is 19.5% (NIOSH, OHSA, MR 217/06 & MR 212/2011).

Oxygen in concentrations higher than the normal 21% do not have injurious effect on humans. This is found to be the case when people use self contained oxygen breathing apparatus. There is no noticeable effect after successive periods of use. High oxygen levels, as used in oxygen breathing apparatus, help people work with less fatigue. However, it is dangerous to breathe pure oxygen while the body is subjected to greater than normal atmospheric pressure (normal being approximately 15 psi).

As stated before, the air in a well-ventilated mine will maintain acceptable oxygen levels unless depleted by some other factor. Those factors include but are not limited to:

(1) Fire or explosion,
(2) Internal combustion engines,
(3) Blasting,
(4) Workers breathing in confined spaces,
(5) Heating conditions in mineral zones
(6) Oxidation of minerals in mineral zones,

(7) Rotting timbers,

(8) Absorption by water or certain types of rocks,

(9) Displacement by other gases either produced underground or issuing from the rock strata (eg: CO_2, CO, SO_2 or, CH_4)

Symptoms Of Oxygen Deficiency

Oxygen Content By Volume	Symptoms And/Or Effects
23.5%	Maximum "Safe Level" - OHSA
21%	Oxygen in Normal air
19.5%	Minimum "Safe Level" – OSHA, NIOSH, MR 217/06, MR 212/2011
17.0%	Impairment of judgment starts to be detected
16.0%	First signs of anoxia appear. Flame is extinguished
16 - 12%	Breathing and pulse rate increases, muscular co-ordination is slightly impaired
14%	IDLH atmosphere as stated by CSA
14 - 10%	Consciousness continuous; emotional upsets, abnormal fatigue upon exertion, disturbed respiration, poor coordination, impaired judgement
10 - 6%	Nausea and vomiting, inability to move freely and loss of consciousness may occur
< 6%	Convulsive movements and gasping respiration occurs; respiration stops and a few minutes later heart action ceases.

Source: OHSA, NIOSH & Industrial Scientific Corporation (Gas Detection Made Easy 2003) & CSA Z94.4 – 02 Selection, Care & Use of Respirators – Appendix H

7.5.2 Carbon Dioxide (CO_2) TLV 5,000 ppm

Carbon dioxide is a colourless, odourless gas and in high concentrations has an acid taste. Carbon dioxide will not burn or support combustion. It is produced by the decomposition or burning of organic materials, in the presence of oxygen. It is a by-product of people and animals breathing.

Carbon dioxide has a specific gravity of 1.98, almost twice as heavy as normal air. Since it is heavier than air, it usually accumulates in low places such as abandoned mine workings or wells. For this reason, people in refuge stations during an emergency must be careful not to lie on the floor and

should move around periodically to ensure the air in the chamber is mixed. Carbon dioxide makes up 0.03% of normal air. The level of carbon dioxide gas in mine air can increase due to internal combustion engines, normal breathing, fires, explosions, and blasting. The presence of carbon dioxide in respirable air can have an adverse effect on humans. The following table shows the effects on humans, as the concentrations of carbon dioxide increase.

Effect Of Carbon Dioxide On Breathing

% Of Carbon Dioxide In Respirable Air	Effect On Respiration
0.03% or 300 ppm	Normal concentration in air.
0.5% or 5,000 ppm	Slight increase in respiration.
2.0% or 20,000 ppm	50% increase in breathing.
3.0% or 30,000 ppm	100% increase in breathing.
5.0% or 50,000 ppm	Cannot be endured for more than a few minutes before serious health consequences up to and including heart failure.

The signs and symptoms of carbon dioxide poisoning are similar to those, which precede asphyxia namely: headache, dizziness, shortness of breath, muscular weakness, drowsiness and ringing in the ears. Concentrations of over five per cent (5%) of carbon dioxide in the air are usually accompanied by reduced oxygen levels. Carbon dioxide levels in mine air should not exceed 0.5% or 5,000 ppm.

Treatment Of Carbon Dioxide Poisoning

Removal from exposure results in rapid recovery. As in all cases of adverse exposure to a contaminant, medical attention should be a prime consideration. Persons affected by carbon dioxide poisoning should be kept at rest and administered pure oxygen until normal breathing is resumed. Qualified personnel should keep patients under observation for a period of time.

7.5.3 Carbon Monoxide (CO) TLV 25 ppm

Carbon monoxide is a colourless, odourless, tasteless, flammable gas. It has the relative weight of 0.967 which makes it lighter than air. It has an explosive range of 12.5% to 74% in air. The TLV of carbon monoxide is 25 ppm. Carbon monoxide is very poisonous and can cause health problems quickly and insidiously.

Carbon monoxide is produced when organic material, wood, paper, oil, gasoline, explosives or any other product yielding carbon, is burned in a limited supply of air or oxygen. Carbon monoxide is believed to be the most common single cause of poisonings both in industry and in homes. Carbon monoxide is one of the products found during blasting operations and in emissions from diesel motors in underground mines. Generally speaking carbon monoxide is the primary contaminant of concern during a mine fire.

How Carbon Monoxide Acts

Carbon monoxide has an affinity (natural attraction) for hemoglobin approximately 200 – 300 times that of oxygen, and by combining with the hemoglobin, renders it incapable of carrying oxygen to the tissues. The effect on the body is therefore predominantly one of asphyxia (O_2 starvation or smothering). The interference of the oxygen supply to the tissues produces the symptoms of carbon monoxide poisoning.

Carbon monoxide in excess of 100 ppm, when breathed continually will eventually produce symptoms of poisoning; 200 ppm will produce slight symptoms after several hours' exposure. When in the presence of 1000 ppm during moderate exercise, palpitation of the heart will occur in 30 minutes and cause one to stagger in 1 hour. In concentrations of 2000 ppm to 2500 ppm unconsciousness usually occurs in about 30 minutes. The effect of higher concentrations may be so sudden one has little or no warning before collapsing.

Effects Of Carbon Monoxide On The Body

Parts Per Million (PPM)	Symptoms
0 - 30	Rarely are there any symptoms. The TLV is 25 PPM
30 - 60	Fatigue may begin to set in
60 - 150	Frontal headache, shortness of breath after 2 to 3 hours
150 - 300	Throbbing headache, dizziness, nausea, diminished manual dexterity & mental abilities, (often unnoticed)
300 - 650	Severe headache, nausea/vomiting, confusion and possible collapse in 1 to 4 hours
700 - 1000	Coma with intermittent convulsions, depressed heart action and respiration, possible death, (in 2 hours @ 800ppm)
1000 - 2000	Potentially fatal impairment of heart & lung functions, collapse and death (in 1 hour at 1600ppm), IDLH – 1200 ppm
2000 - 2500	Unconsciousness in about 30 minutes and possible death
3200	Symptoms in 5 to 10 minutes, sudden collapse and death in 30 minutes
6400	Symptoms in 1 to 2 minutes, unconsciousness and death in 10 to 15 minutes
12,800	Immediate unconsciousness & death in 1 to 3 minutes with no warning symptoms

Reference: NIOSH, Industrial Scientific Gas Detection Made Easy June 2003

The rate at which persons are overcome and the sequence in which the symptoms appear depend on several factors;

- the concentration of gas
- the extent to which they exert themselves
- state of their health
- individual susceptibility
- the temperature, humidity and air movement (environment) to which they are exposed

Treatment Of Carbon Monoxide Poisoning

Carbon monoxide is expelled from the body through the lungs, when air free of carbon monoxide is breathed. Over half the carbon monoxide is eliminated in the first hour when the exposure has been moderate. In all cases of carbon monoxide poisoning, medical attention should be sought in order to determine the degree of poisoning. Treatment for carbon monoxide poisoning includes:

- Administration of pure oxygen until the carboxyhemoglobin level returns to normal. The oxygen should be administered for 20 to 30 minutes in mild cases and as long as one or two hours in more severe cases.
- No stimulant drugs should be administered.
- The patient should be kept at rest, preferably lying down for 24 - 48 hours to avoid strain on the heart, later they should be given plenty of time to rest.
- Patient must be watched for late neurological and/or cardiac complications.

7.5.4 Hydrogen (H_2)

Hydrogen is a colourless, odourless, tasteless gas. It has a specific gravity of 0.09, which means it is lighter than air. It is not harmful to breath, but is combustible with an explosive range of 4.1 to 74% in air. It will displace the oxygen in the area when in a high concentration. In addition, if present at the time of a mine fire, it may combine with carbon to form explosive concentrations of hydrocarbons.

Hydrogen is found in normal air in very small quantities. It is sometimes found in the mine atmosphere during or after a fire, particularly when the rocks have been heated to incandescence and sprayed with water. It is also a product of the electrolytic action when wet batteries are being charged.

7.5.5 Hydrogen Chloride (HCL) Ceiling 2 ppm

Hydrogen Chloride is a colourless very irritating gas with a pungent odour, which is given off when certain types of conveyor belting or plastics burn. It has a specific gravity of 1.19 and is non-flammable. It is an irritant to the

upper respiratory passages (35 ppm) and in higher concentrations can irritate the eyes. This occurs when the hydrogen chloride gas is in contact with the moisture of the body it turns to hydrochloric acid. Workers who are regularly exposed to hydrochloric acid or hydrogen chloride may suffer erosion of the teeth. Concentrations of 50 - 100 ppm are barely tolerable for one hour. Concentrations of 1,000 - 2,000 ppm are dangerous even for brief exposures and may be fatal. Hydrogen chloride does not poison through the skin but it can cause irritation or burns to the skin because it turns to hydrochloric acid when combining with the moisture of the body.

The treatment for exposure to hydrogen chloride consists of quickly assessing for an open airway, ensuring adequate respiration and pulse. Transport to medical attention ASAP.

7.5.6 Hydrogen Sulphide (H_2S) TLV 1 ppm

Hydrogen sulphide is a colourless gas and is one of the most poisonous gases known. Fortunately, only traces of it are found in mines. Hydrogen sulphide has a distinct rotten egg odour in low concentrations. Odour threshold is 0.01 to 0.3 ppm. In concentrations of 100 ppm or more the sense of smell is quickly paralyzed and cannot be relied on for warning. The gas has a specific gravity of 1.19 and, being heavier than air, may collect at low points. A mixture of 4.3 to 46% of hydrogen sulphide in air is explosive.

Hydrogen sulphide inhaled in a sufficiently high concentration produces immediate asphyxiation; in low concentrations it produces inflammation of the eyes and respiratory tract and sometimes leads to bronchitis and pneumonia.

Symptoms of hydrogen sulphide poisoning may occur at exposure to concentrations as low as 50 ppm. Immediate collapse usually results from exposure to concentrations of 600 ppm to 1000 ppm and death quickly ensues.

Hydrogen sulphide occurs naturally in crude oil, natural gas wells. Hydrogen sulphide can be released during the decay of sulphur containing organic materials in the absence of oxygen and presence of water. It is often called “stink damp” or ”swamp gas”. When it is released to the air, it will change into sulphur dioxide and sulphuric acid. When blasting in sulphide ore bodies, the resulting gases may contain varying amounts of hydrogen sulphide, along

with sulphur dioxide and possibly other sulphur gases.

Treatment

Rescuers must wear a SCBA to enter the area in order to remove a victim to fresh air. Administer oxygen as soon as possible. Admit to doctor's care as soon as possible advising the doctor of the nature of the poisoning. They should be monitored for at least 48 hours.

7.5.7 Methane (CH_4)

Methane is a colourless, odourless, tasteless gas, but may be accompanied with an odour if found in the presence of other gases such as hydrogen sulphide. Methane will burn with a pale blue non-luminous flame in still air that contains 5 to 15% methane and 12% or more of oxygen.

Methane is highly explosive, however, the flammable and explosive range of methane is variable and therefore, all occurrences of the gas should be considered dangerous. Where the presence of methane is suspected or known, adequate ventilation must be maintained in order to dilute the gas to non-flammable or explosive levels. Methane is considerably lighter than air and when found in mines is usually near the roof or concentrated in high places.

Accumulations of the gas may be encountered in unused and poorly-ventilated mine workings, or when old workings are being de-watered. Methane is produced by the decaying of organic materials (eg. old timbers) in the presence of water and absence of oxygen. Methane has no direct effect upon people unless it displaces oxygen in the air to such an extent as to cause oxygen deficiency. An open-flame or a spark may cause an explosion.

7.5.8 Oxides Of Nitrogen (NO, NO_2, etc.) TLV For NO_2 Is 3 ppm

Oxides of nitrogen are formed in mines by the burning or detonation of explosives and by diesel exhaust. Exposure to oxides of nitrogen may affect the respiratory passages and result in death even when breathed in small quantities. A person who has been exposed to oxides of nitrogen may appear to recover in a short time, only to become very ill and die a few days later from pulmonary edema.

Nitrogen Dioxide (NO_2) is perhaps the most irritating of the oxides of nitrogen. It is produced by the reaction of nitrogen and oxygen during the combustion process. When a person is exposed to 100 ppm of nitrogen dioxide, serious health effects will occur even if breathed for a short time. Concentrations of less than 500 ppm can be fatal if breathed for 30 minutes or less. Its effect on the respiratory passages usually becomes apparent several hours after exposure when edema and swelling take place. This irritation may be followed by bronchitis or pneumonia, often with fatal results.

Signs and symptoms of exposure to oxides of nitrogen include difficulty breathing, low blood pressure, slight cough or choking, edema, headache (pounding), constipation, fatigue, loss of appetite and nausea.

Treatment

Persons exposed to oxides of nitrogen, even in small amounts should receive medical attention for appropriate treatment. If oxygen is administered it should be done by atmospheric enrichment rather than aggressive oxygen therapy. Advise the hospital of the nature of gassing and patient should be kept at rest and observed for delayed edema.

7.5.9 Sulphur Dioxide (SO_2) STEL 0.25 ppm

Sulphur dioxide is a colourless, non-flammable gas with a specific gravity of 2.9. It is often produced when sulphide ores are heated, burned or blasted. During combustion, some diesel fuels will also produce sulphur dioxide. This gas will dissolve in water, which is why, when a mine rescue team enters an area where a sulphide blast has occurred and there is standing water; walking through the water will release SO_2 and cause a spike on monitoring equipment.

Sulphur dioxide has a strong sulphur smell, which is suffocating and very irritating to breathe. If exposed to sulphur dioxide, coughing and nausea will result. This gas will affect the lungs in much the same manner as oxides of nitrogen and hydrogen sulphide, irritating the respiratory tract causing edema.

Signs and symptoms of exposure to sulphur dioxide include shortness of breath, pulmonary edema, burning in chest, coughing, nausea and pneumonia. These symptoms will be greatly enhanced if the patient already

has a pulmonary disease such as asthma or bronchitis.

Treatment

Remove the person to fresh air. Administer oxygen and if the person is not breathing administer artificial respiration. Persons exposed to sulphur dioxide, even in small amounts need to receive medical attention for appropriate treatment.

7.5.10 Vinyl Chloride (CH_2CHCl) TLV 1 ppm

Vinyl chloride can be produced by fires involving vent tubing, pvc pipes, rubber, wire coverings or other products made with PVC – polyvinyl chloride. It does not occur naturally. It has an ether like or sweet odour. Usually what is smelled is a smell of burnt plastic. Specific gravity is 2.2. Vinyl chloride is flammable at room temperature and has an explosive range from 3.8 to 29%. It is also water-soluble.

It is a known human carcinogen and can cause liver cancer. Breathing high levels of vinyl chloride (10,000 ppm) can cause you to feel dizzy or sleepy.

Treatment

Administer oxygen when available and get to medical attention. There is no antidote for vinyl chloride exposure. Treatment consists of quick assessment for an open airway and ensure adequate respiration and pulse. Transport to medical attention ASAP.

7.5.11 Ammonia (NH_3) TLV 25 ppm

As mining methods today involve more use of cement grout, cable bolts, & shotcrete for ground control, it is important to understand ammonia gas is produced when any of these come into contact with anfo or amex. Ammonia can also be released when hydraulic backfill or cement paste fill is used for stope backfilling and it comes in contact with anfo or amex.

Ammonia is flammable and colourless. It has a sharp or pungent, intensely irritating odour that can be described as suffocating. Odour threshold is 1 to 50 ppm. It has an explosive range of 15 to 28%. The odour is detectable below 5 ppm. When mixed with water it is known as Ammonium Hydroxide.

The specific gravity of Ammonia is 0.6.

The TLV is 25 ppm with a STEL of 35 ppm. The simplest way to determine the ammonia concentration is to use colourimetric tubes. There are electronic monitors available.

Treatment

Take the victim to fresh air, keep at rest and seek medical help.

7.5.12 Other Gases

Depending on the fuel and the location, a mine fire can produce many different toxic gases. A burning conveyor belt can produce hydrogen chloride, vinyl chloride and methyl chloride in addition to the common products of combustion.

Mine Rescue Teams must always be aware of this and be prepared for the unexpected.

7.6 Chart Of The Properties Of Gases

The following chart is included to provide mine rescue personnel with a quick reference for the various gases that could be encountered during a mine emergency. The column titled “Lighter or Heavier than Air” is provided to assist mine rescue people locate specific gases under ideal, “still air” conditions. When mine rescue personnel are sampling for gas concentrations, they should sweep the area as well as sample where a gas might occur because of its weight.

7.6 Chart Of The Properties Of Gases

GAS TYPE	TLV	IDLH	Chemical Symbol	Lighter Or Heavier Than Air	Combustible or Explosive	Explosive Range By %	Colour	Odour	Taste	Dangerous To Breathe
Acetylene	-	-	C_2H_2	Lighter	Yes	2.5 - 81%	No	Intoxicating	Sweet	No
Ammonia	25	300	NH_3	Lighter	Yes	15 – 28%	No	Irritating & Pungent	Alkaline	Yes
Carbon Dioxide	5000	40000	CO_2	Heavier	No	None	No	No	Acid	Yes
Carbon Monoxide	25	1200	CO	Lighter	Yes	12.5 - 74%	No	No	No	Yes
Hydrogen	-	-	H_2	Lighter	Yes	4.1 - 74% in 5% O_2	No	No	No	No
Hydrogen Chloride	Ceiling 2	50	HCl	Heavier	No	None	No	Pungent & Irritating	No	Yes
Hydrogen Sulphide	1	100	H_2S	Heavier	Yes	4.3 - 46%	No	Rotten Eggs	No	Yes
Methane	1000	-	CH_4	Lighter	Yes	5.-.15% in 12% O_2	No	No	No	No
Nitrogen	-	-	N_2	Lighter	No	None	No	No	No	No
Nitrogen Dioxide	3	20	NO_2	Heavier	No	None	Red	Sweet Bleach Like	Acid	Yes
Oxygen	-	14	O_2	Heavier	No	None	No	No	No	No
Propane	1000	-	C_3H_8	Heavier	Yes	2.5 - 9.5%	No	Odour Like Stench Smell	Rotten	No
Sulphur Dioxide	STEL 0.25	100	SO_2	Heavier	No	None	No	Sharp	Acid	Yes
Vinyl Chloride	1	-	CH_2CHCl	Heavier	Yes	3.8 - 29%	No	Sweet – Ether Like	No	Yes

A dash does not correspond to zero but only means there is no data given. TLV, STEL & IDLH numbers represent PPM.

TLV & STEL values taken from the 2011 TLV's for Chemical Substances and Physical Agents & Biological Exposure Indices of ACGIH Worldwide. IDLH figures are from NIOSH Pocket Guide To Chemical Hazards. Propane (C_2H_3) & Methane (CH_4) are Aliphatic Hydrocarbon Gases and do have a TLV of 1000 PPM but the main danger of these gases are their explosive ranges.

7.7 Gas Detection

Gas detection is an important part of any rescue or recovery operation. A Mine Rescue Team should make frequent tests for gases as it advances beyond the fresh air base. Knowing the levels of contaminants in the atmosphere may provide the necessary information to initiate corrective action. For example, high levels of methane may require ventilating an area of the mine; high carbon monoxide levels could indicate the presence of a smoldering fire and alert the team to an explosion hazard etc.

Knowing what gases are present and in what concentration, provides a team with important clues as to what has happened in the mine. Mine Rescue Team members must know the properties of various gases, know where to test for their presence and how to react when they are detected.

Some gases may be detected by smell, taste or even sight and irritation. While this will not tell us how much is present it does provide an indication. Do not rely on your senses to tell you there is a contaminant in the atmosphere, use proper gas detection equipment to determine a proper reading or concentration. The charts on pages 21 & 22 will assist with their detection, recommend detection methods and when to test.

7.7.1 Flame Safety Lamp

After considerable discussion at the November 2004 Instructor's Meeting, it was agreed the flame safety lamp would no longer be a mandatory component of standard mine rescue equipment.

The flame safety lamp may still be used by mine rescue teams but it was stressed more dependable gas detection equipment is currently available.

In future, mine rescue teams must utilize primary gas detection equipment as well as back-up or secondary detection equipment when on a mission. In addition, gas detection equipment must be able to function as an explosive meter, gas detector and oxygen analyzer. All gas detection devices must be maintained according to the manufacturer's specifications.

In the event a primary detection device fails or provides erratic reading and cannot be verified by the secondary equipment, the team will discontinue the mission until appropriate equipment can be obtained.

If conditions are known, and the Captain, Team Members and Director of Operations are confident that risk factors associated with the mine rescue mission will not compromise the safety of mine rescue team members; a decision to continue may be made.

7.8 Electronic Gas Monitor Sensor Cross Sensitivity / Interference

As the use of electronic gas monitors becomes more prevalent, Mine Rescue personnel must be aware of the fact sensors in these pieces of equipment may show false readings if exposed to a gas that has a cross sensitivity / interference with the detector's sensor.

The following chart lists the sensor and the gases that may cross interfere with it.

Monitor Sensor	Gases That Cause Cross Interference
CO	H_2, H_2S, SO_2, NO, Alcohols & Olefins. Cl_2 & NO_2 Cause A Negative Effect.
SO_2	H_2S, HCN, H_2, PH_3, Cl_2, Acetylene, & Mercaptans. NO_2 Causes A Negative Effect.
O_2	No known interferences although displacement may give lower readings.
NO_2	Cl_2, & CO. Negative effects from H_2S, PH_3, SO_2, HCN, H_2, Acetylene, and Methanol
H_2S	PH_3, NO, SO_2, H_2 & Mercaptans. Negative effects from Cl_2
H_2	CO, NO, SO_2, HCN, PH_3, Ethylene, Acetylene and Methanol. Negative effects from Cl_2 & NO_2.
CO_2	Minimal Effect From Most Gases In TLV Range

Sources: Draeger and Industrial Scientific

Figure 7.2 – Draeger PAC III Single Gas Monitor

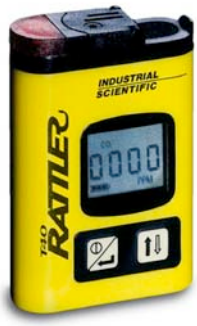

Figure 7.3 – Industrial Scientific T 40 Rattler Single Gas Monitor

Figure 7.4 – Draeger Pac 3500 Single Gas Monitor

Figure 7.5 – Koehler Flame Safety Lamp

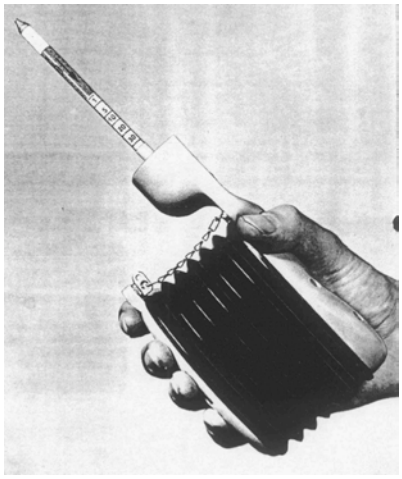

Figure 7.6 – Draeger Multi Gas Detector.

Figure 7.7 – Draeger Accuro Multi Gas Detector

Figure 7.8 – MSA Altair Single Gas Monitor

Figure 7.9 – Industrial Scientific ITX Multi Gas Detector

Figure 7.10 – Gastec Multi Gas Hand Pump

Figure 7.11 – Draeger X-am 5000 Multi Gas Detector

Figure 7.12 – Draeger CMS Gas Detector

Figure 7.13 – Industrial Scientific M 40 Multi Gas Detector

7.9 Charts Of Gas Detection

Gas	Sight	Smell	Taste	Symptoms Of Exposure
Oxygen Deficiency	No	No	No	Dizziness, buzzing ears, rapid heart beat, headaches
Carbon Dioxide (CO_2)	No	No	Acid	Respiration getting faster and deeper
Carbon Monoxide (CO)	No	No	No	Throbbing headache, weakness, dizziness, nausea
Hydrogen Sulfide (H_2S)	No	Rotten eggs, high concentration paralyses sense of smell	No	Inflammation of eyes and respiratory tract
Sulphur Dioxide (SO_2)	No	Pungent sulphurous	Acid	Irritation to respiratory tract
Nitrogen Dioxide (NO_2)	Reddish brown in high concentrations	Sweet or Bleach Like	Acid	Irritation to respiratory tract
Ammonia (NH_3)	No	Pungent, possible smell impairment	Alkaline	Irritation to eyes, nose, skin and respiratory tract headaches nausea
Chlorine (CL_2)	Greenish yellow	Pungent	No	Irritating to skin, eyes and mucous membranes, cramps in the larynx muscles (choking)
Formaldehyde (CH_2O)	No	Pungent	No	Severe irritation to respiratory tract and eyes
Hydrogen Cyanide (HCN)	No	Bitter almonds	No	Slight irritation to nose and throat (can be absorbed through skin)

Gas	Detection Methods	When To Test
Oxygen (O_2)	Electronic Oxygen Monitor Chemical analysis.	During any team exploration.
Carbon Dioxide (CO_2)	Carbon dioxide detector. Multi-gas detector. Chemical analysis.	After a fire or explosion. When entering abandoned areas. When reopening sealed areas.
Carbon Monoxide (CO)	Carbon monoxide detector. Multi-gas detector. Chemical analysis.	During any team exploration, especially when fire is suspected.
Nitrogen Dioxide (NO_2)	Nitrogen dioxide detector. Multi-gas detector. Chemical analysis. Colour.	After mine fire or explosion. When diesel equipment is used. After detonation of explosives.
Ammonia (NH_3)	Ammonia detector. Multi-gas detector. Odour & irritation of nose and throat	Anfo or Amex contacting cement, shotcrete, or grout
Hydrogen (H_2)	Multi-gas detector. Chemical analysis.	After mine fire or explosion. Near battery-charging stations. When steam is produced by water, mist or foam in fire-fighting.
Hydrogen Sulphide (H_2S)	Hydrogen sulphide detector. Multi-gas detector. Chemical analysis. Eye irritation.	In poorly ventilated areas. During unsealing operations. Following mine fires.
Sulphur Dioxide (SO_2)	Multi-gas detector. SO_2 detector Chemical analysis. Odour, taste and respiratory tract irritation.	When standing water is disturbed. After mine fires or explosions and when reopening sealed areas of the mine after mine fires.
Methane (CH_4)	Methane detector. Chemical analysis.	During any team exploration. When normal ventilation is disrupted. When entering abandoned workings.
Heavy Hydrocarbons Ethane (C_2H_6) Butane (C_2H_8) Propane (C_4H_{10})	Multi-gas detector. Chemical analysis. LEL on electronic detectors	Following fires or explosions when methane is present. Following accidental entry into adjacent oil or gas well casings.

7.10 Review Questions

1) Describe the components of air and list some of the characteristics of each component.

2) What are the components of normal air and the percentages of each gas?

3) What is the concentration (in ppm) of oxygen in normal air?

4) What is the normal percentage of oxygen in exhaled breath?

5) What are the requirements of air for one person for one hour before they begin to suffer from lack of breathable air?

6) What is an inert gas?

7) Is an inert gas dangerous?

8) Assuming that a person taking refuge in a dead end drift consumed 1 cubic metre of air per hour, how long could 12 people survive if the refuge area measured 3 x 5 x 30 metres?

9) What are the definitions of the following terms?

    a) C.O.T -

    b) Solubility -

    c) Specific Gravity -

    d) Flammability -

    e) Explosive Range -

10) At what percent of oxygen is it at the minimum "safe level"?

11) What can cause air in a mine to become contaminated or become oxygen deficient?

12) Under what conditions might it be dangerous to breathe pure oxygen?

13) At what percentages of oxygen would one possibly lose consciousness without prior warning after a relatively short period of time?

14) At what oxygen concentration is a person's judgment impaired, and when would they lose consciousness?

15) How is carbon dioxide formed?

16) What are the properties of carbon dioxide?

17) Will carbon dioxide burn or support combustion?

18) Is carbon dioxide heavier or lighter than air and where can it be found?

19) What concentration of carbon dioxide would cause a 50% increase in your rate of respiration?

20) With most people what is the main symptom of higher than normal carbon dioxide levels?

21) What concentration of carbon dioxide would cause a 100% increase in your rate of respiration?

22) What concentration of carbon dioxide cannot be endured for a long period of time?

23) What are the physical properties of carbon monoxide?

24) How is carbon monoxide produced?

25) At what percentage will carbon monoxide explode?

26) What are some symptoms of CO poisoning at different levels of exposure?

27) The treatment for carbon monoxide poisoning would include;

28) The primary gas hazard after a mine fire is?

29) How does CO affect a person exposed to higher than normal levels?

30) As a rescuer how would you take care of a patient that has been exposed to high levels of CO?

31) What are the properties of hydrogen?

32) What is the explosive range of hydrogen?

33) How is hydrogen produced?

34) What are the main dangers of hydrogen and methane?

35) What are the physical properties of hydrogen chloride?

36) How long could you be exposed to hydrogen chloride at the following concentrations?

50 to 100 ppm

1000 to 2000 ppm

37) How is hydrogen chloride formed?

38) What are the physical properties of hydrogen sulphide?

39) How can hydrogen sulphide be recognized?

40) How is H_2S produced?

41) How does breathing hydrogen sulphide affect a human being?

42) At what percent by H_2S does

a) sub-acute poisoning occur?

b) death occur?

43) H_2S is explosive, what is the range?

44) Why is H_2S so dangerous?

45) What are the physical properties of methane?

46) How is methane formed?

47) Why is methane dangerous?

48) Being that it is explosive, what is the explosive range?

49) Why should a mine rescue team retreat when flammable gas is encountered and the level is close to or over the LEL?

50) You see a 50% LEL reading on your gas monitor, what does that mean?

51) What are the physical properties of oxides of nitrogen?

52) How is oxides of nitrogen formed?

53) What are the symptoms of oxides of nitrogen poisoning?

54) At what percentages do oxides of nitrogen

a) cause dangerous illness?

b) cause death?

55) How is treatment for nitrogen dioxide to take place?

56) What are the physical properties of sulphur dioxide?

57) How is sulphur dioxide formed?

58) Your team is in a stope where there has been a sulphide blast, the air is clear and no gas readings, you are walking through water and suddenly your sulphide detector registers a reading, why?

59) What are some signs and symptoms of SO_2 poisoning?

60) What is the treatment for exposure to SO_2?

61) How is vinyl chloride formed?

62) What are the physical properties of vinyl chloride?

63) Is vinyl chloride explosive and if so what is the range?

64) What is the other danger of vinyl chloride?

65) What are the physical properties of ammonia?

66) How is ammonia formed?

67) Is Ammonia explosive and what is the range if it is?

68) What treatment should be given?

69) What are the TLV's for these common gases that could be found in a mine?

Ammonia -

Carbon dioxide -

Carbon monoxide -

Hydrogen chloride -

Hydrogen sulphide -

Nitrogen dioxide -

Sulphur dioxide -

Vinyl chloride -

70) What are the explosive ranges of the following gases?

Carbon monoxide -

Hydrogen -

Hydrogen sulphide -

Methane –

71) When there is an accumulation of any of the following gases, are they heavier or lighter than air?

Methane -

Carbon dioxide -

Carbon monoxide -

Hydrogen sulphide -

Sulphur dioxide -

Nitrogen dioxide -

Hydrogen -

72) What instruments can be used to detect a low O_2 condition?

73) Name some different types of gas detection instruments used by mine rescue.

74) Cross sensitivity or cross interference is when an electronic sensor designed to detect a specific gas detects a different gas and falsely displays a reading of the gas it is designed to detect. What are some gases that can cause cross sensitivities with sensors?

75) Two types of electronic gas detection sensors are not affected by other gases, what sensors are they?

76) What can cause an electronic gas monitor to give false readings even though it is properly calibrated?

77) How much air does the bellows of the Draeger Multi-Gas Detector hold?

78) If the basic squeeze is one and no reading has been obtained, how many more squeezes can be given on the Draeger Multi-Gas Detector?

79) Can a tube be reused if no color is obtained?

80) How is the Draeger Multi-Gas Detector tested for tightness?

81) Is the nose a reliable source for gas detection?

LEARNING OBJECTIVES AND TARGET AUDIENCE

SECTION 8
GENERAL MINE RESCUE TEAM PRACTICES & PROCEDURES

Learning Objectives

Section 8 provides general and specific information about how a Mine Rescue Team is structured and how it should conduct its business during practice sessions or in the event of an emergency.

Suggested Target Audience

Section Number	Topic	Basic Mine Rescue Trainees	Standard Mine Rescue Trainees	Advanced Mine Rescue Trainees	Mine Rescue Equipment Technicians	Mine Rescue Instructors	Director Of Operations & Resource Personnel	Senior Management Personnel	Supervisors	New Or Transferred Employees
8.1	The Mine Rescue Team	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
8.2	Objectives Of Rescue & Recovery Work	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
8.3	Safety Of The Team	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
8.4	Team Procedures	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
8.5	Signals	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
8.6	Route Of Travel	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
8.7	Marking Route Of Travel	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
8.8	Link Lines	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
8.9	Stretcher Procedures	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
8.10	Stretcher Drills	**Yes**	**Yes**	**Yes**		**Yes**				
8.11	Size Of Mine Rescue Teams	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
8.12	Role Of The Mine Rescue Team Captain	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			

Suggested Target Audience (continued)

Section Number	Topic	Basic Mine Rescue Trainees	Standard Mine Rescue Trainees	Advanced Mine Rescue Trainees	Mine Rescue Equipment Technicians	Mine Rescue Instructors	Director Of Operations & Resource Personnel	Senior Management Personnel	Supervisors	New Or Transferred Employees
8.13	General Mine Rescue Emergency Response Procedures	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
8.14	Duration Of Mine Rescue Mission	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
8.15	Care Of Personnel Found In The Mine	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		
8.16	Mine Rescue Work Utilizing Mobile Equipment	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
8.17	Guidelines For The Use Of Personnel Carriers During A Mine Emergency	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
8.18	Using Shaft Conveyance Without Communications	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
8.19	Communications For Mine Rescue	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
8.20	Specialized Procedures For Non-Emergency Mine Rescue Activities	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	
8.21	Review Questions	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		

Section 8. General Mine Rescue Team Practices And Procedures

8.1 The Mine Rescue Team

The working unit of mine rescue, the team, is a very important concept. Simply stated, a "team" is a unit made up of individuals working toward a common goal.

A mine rescue team is composed of individuals, each with specific skills and responsibilities. Team members must function within their own area of expertise as well as within the structure of the team unit. For example, the team captain is responsible for the safety of the team and for managing the emergency response mission in the mine. The number two team member may have responsibility for measuring ventilation flows and gas detection. Although all team members share similar training they must work independently and collectively in order to fulfil the objectives of a mission or emergency response.

The captain of the mine rescue team has a very important role to play. The captain functions as the team's on-the-field leader, much like the quarterback on a football team. The team captain "calls plays" by making decisions based on the team's abilities and the conditions they're working in. The captain leads the team and sets the pace during practice sessions and actual rescue work.

The prime consideration of any mine rescue team must always be:

THE SAFETY OF THE MINE RESCUE TEAM MEMBERS.

Without the team, there would be no rescue and no recovery.

When mine rescue personnel arrive at the station responding to an emergency, members must prepare to be dispatched. Upon arrival they need to change and begin getting equipment ready to take into the mine. They need to get out their BG 4's and prepare them to go into service (eg: field test, ice, anti-fog facepiece). They should draw and test any equipment needed, depending on the emergency (eg: gas monitors, fire equipment, self rescuers, first aid equipment, etc). Doing this will help the Captain get the team together and speed up the response time.

Mine rescue teams must always assess each situation before making the decision to act. They should never commit to an activity that threatens the lives of the team members, regardless of how "heroic" it may seem. Losing sight of sound judgement, in favour of heroism is foolhardy - and dangerous.

8.2 Principles Of Rescue And Recovery Work

Fundamental principles of Mine Rescue in order of importance are:

(1) Ensure the safety of the mine rescue team and its members.

(2) Take the necessary steps to rescue or safeguard mine personnel who are at risk.

(3) Protect the mine property from further damage.

(4) Rehabilitate the mine.

In general, the initial job of the mine rescue team is to explore the mine, conducting whatever work is necessary to determine the scope and extent of a mine emergency. When mine personnel are found, the team is to treat, rescue or protect them and to note and record conditions found in the mine. Information gathered during exploration must be recorded and relayed to the director of operations. The director of operations is normally located in the emergency response control centre.

Once the mine rescue team has provided critical information to the control centre, support personnel such as engineers, geologists, electricians or ventilation specialists are able to process the information and provide the director of operations with information to direct the mine rescue team.

At all times, when direction is being given to the mine rescue team, there should be an opportunity for the team to discuss those directions and to provide input as required. It is important to remember that the mine rescue team is the eyes and ears of an emergency response operation and may have knowledge of conditions or circumstances that the control centre would not. This collective information should be the basis of a course of action. An inappropriate, or hasty decision by any person involved in the emergency response mission could have disastrous results. Mine rescue teams are encouraged to question decisions, but unless there is some compelling reason not to carry out their orders, they should act as directed. Mine rescue teams should not act independently of the control centre.

When the director of operations or other persons in the control centre provide direction to the mine rescue team, they should consider the following criteria;

- conditions in the mine where the mine rescue team will be working,
- route of travel,
- visibility,
- familiarity with the area of work,
- complexity of the emergency,
- number of rescue teams available and the limitations of both personnel and apparatus,
- if using vehicles, the hazards that might be associated with their use,
- distance of travel and the limitation of the apparatus in event that a vehicle fails,
- communications between the rescue team and control centre,
- availability of emergency equipment and emergency response materials,
- any other factor that may jeopardize the safety of the mine rescue team.

8.3 Safety Of The Team

The safety of the mine rescue team is of primary importance. The captain has a responsibility for the safety of team members and must make whatever decisions necessary to ensure the team exits the mine safely. It is understood that, when a mine rescue team enters a mine during a mine emergency they may be placing themselves at significant risk. Therefore, it is important for the team to assess conditions and circumstances in the mine carefully in order to make appropriate decisions to reduce risk factors to the lowest level possible. The team captain should give each situation encountered underground careful thought before proceeding; in plain words, the captain should ensure the odds are in the mine rescue team's favour at all times.

8.4 Team Procedures

Good discipline among team members, at all times, is of the utmost importance. Team members must be trained to follow the instructions of the control centre and the team captain. It is important for the team captain to be competent in mine rescue principles and procedures. Team members must have confidence in the captain's ability to lead the team and make logical and practical decisions. If discipline or confidence is lacking in the team unit, the team's efficiency or safety may be in jeopardy.

The team captain should lead the team at all times, although there are times, conditions permitting, when another team member will assume the lead, for a limited period of time.

The mine rescue team should advance through the mine cautiously, checking the mine atmosphere, assessing ground conditions, and looking for other situations that may pose a problem for the mine rescue team or the mine.

8.4.1 Examining Unexplored Territory

When examining unexplored territory, the team captain should lead the team but must rely on the expertise of the team members to help with the assessment of conditions.

8.4.2 Moving With A Victim Through Unexplored Territory

When it is **necessary** to move a victim through unexplored territory it will only be done after assessing risk factors such as travel conditions, distance, condition of the victim and other factors determined by the nature and circumstances of the emergency. Wherever practical, the decision to proceed is to be made in conjunction with the team's Director of Operations. However when conditions will not pose further risk to the victim, the team may transport the victim through unexplored territory.

The key point of this issue is that once the decision has been made to move the victim they must remain under the care and control of the Mine Rescue team and can never be placed at unnecessary additional risk.

8.4.3 Passing Through Doors Or Stoppings

In today's mines, ventilation control doors or "stoppings" found in mine workings are often very large. Erecting back seals or pocket seals to pass through these obstacles is impractical and unnecessary.

The following guidelines apply when passing through ventilation doors or "stoppings";

(1) Conditions on both sides of the stopping must be established.

(2) Opening the door must not make the mine emergency any worse.

(3) The mine rescue team must pass through as quickly and efficiently as

possible.

(4) Unless the effect of a change is known, doors or conditions must remain the same way they were found.

8.4.4 Resting And Checking The Team

Resting and checking the mine rescue team is very important.

Under normal circumstances, a mine rescue team should be rested and checked;

(1) Every 15 -20 minutes of mission activity,

(2) After strenuous work,

(3) As conditions in the mine dictate.

In addition, a mine rescue team should be checked;

(1) Prior to entering the mine *(to check and encourage each team member)*,

(2) Immediately after entering the mine *(to check readiness of team to continue and to acclimatise to conditions),*

(3) Prior to entering a contaminated atmosphere, *(to check readiness of team and condition of equipment),*

(4) Immediately after entering a contaminated atmosphere, *(to check readiness of team to continue, take tests and to acclimatize to conditions),*

Team rests and checks fulfill five primary purposes:

(1) Allows the captain to assess the physical and mental state of each team member,

(2) Allows the team to rest and compose themselves

(3) Provides an opportunity to discuss team progress to date or planned activity,

(4) Provides the opportunity to record oxygen cylinder pressures.

(5) Allows team members an opportunity to adjust or familiarize themselves with their surroundings.

Work conducted by the mine rescue team should, be distributed equally. This will ensure that one team member is not overworked.

8.5 Signals

Movement, or direction signals are generally given to a mine rescue team by using a horn or similar device. Although this is a procedure carried over from the days when breathing apparatus had mouthpieces and did not allow voice communication, it is still an efficient method to communicate with the team.

Horn Signals

One.....Stop

Two.....…Advance

Three.....…Turn Around

Four.....….Distress or Attention

When the captain gives the mine rescue team a horn signal, it must be repeated by the vice captain and visa versa.

8.6 Route Of Travel

Wherever possible or practical, a mine rescue team must explore a mine via the fresh air route. There are two fundamental reasons for travelling in fresh air;

(1) The danger to an exploring team is lessened.

(2) Visibility will be better.

If travel in the fresh air route is not practical or possible, an alternate route must be selected. When following any route other than the fresh air route, mine rescue teams must exercise extreme caution and take all necessary measures to ensure they have a safe and assured route back to the fresh air base.

8.7 Marking Route Of Travel

Most modern day mines are often very large, have intricate networks of tunnels and mine workings and may be accessible by motorized transportation only. In these circumstances, marking route of travel in the traditional manner is not practical. In addition, the use of various communication devices whereby a mine rescue team is in constant contact with the control centre further challenges the practicality of utilizing traditional methods to mark route of travel.

There are however good reasons for marking route of travel especially in the area

where a mine emergency has occurred. Reasons for marking route of travel include;

(1) It enables the mine rescue team to find its way back to the fresh air base.

(2) It indicates to a second team what areas have been examined by the preceding team.

(3) It provides the shortest route of travel to locate a mine rescue team who may require assistance.

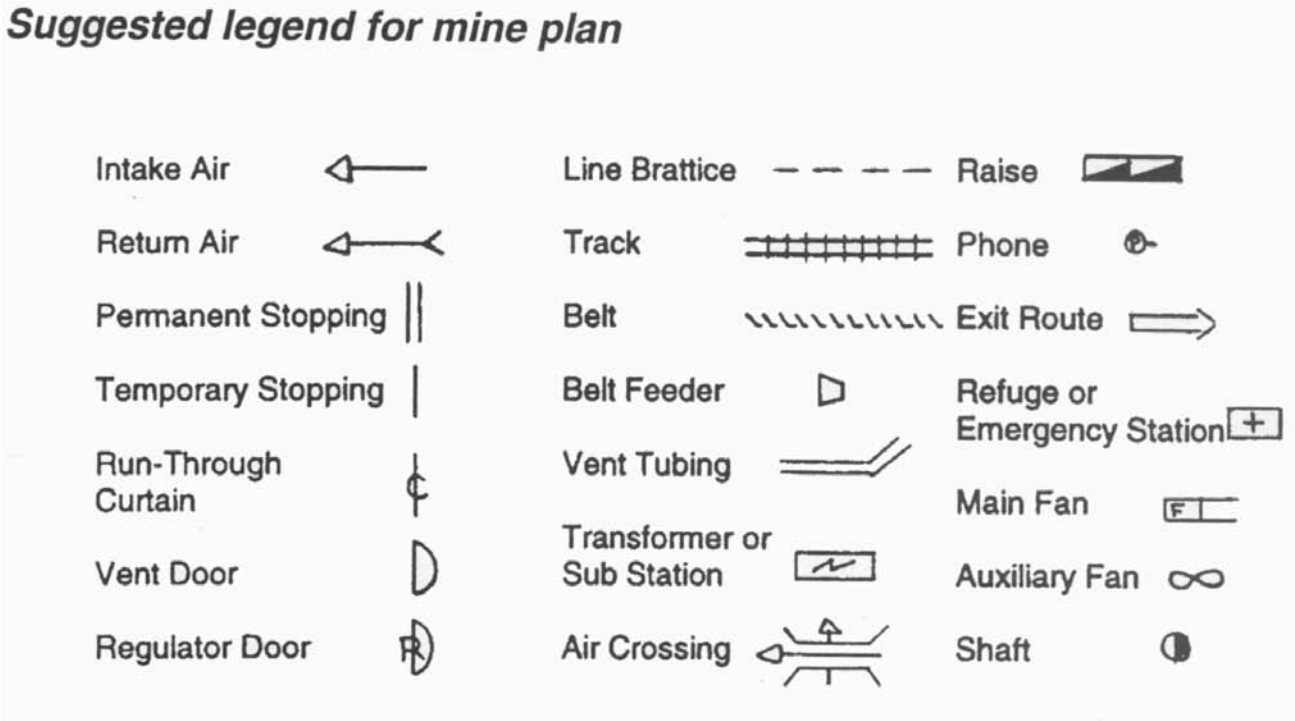

Figure 8.1 – Example of a map legend that may be used by Mine Rescue Teams

8.7.1 Methods Of Marking Route Of Travel

Arrows

One way of marking route of travel is using arrows that point back to the fresh air base. Arrows are usually marked on the wall with chalk or spray paint. A number that identifies the mine rescue team is often written above or beside the arrow. When a mine rescue team retreats from a mine each arrow is cancelled by marking over them with an **X**.

Guidelines

Guidelines or communication cables are also a consideration for marking route of travel. Guidelines should begin at a shaft station or fresh air base and travel with the mine rescue team to the source of the emergency. If guidelines or communication cables are used, arrows, as described above, must also be used.

Track Switches

Setting track switches so the mine rescue team has clear track back to the fresh air base may also be a consideration for marking route of travel.

Roadboards Or Flagging Tape

The use of roadboards or flagging tape is perhaps the most common method to mark route of travel. By placing a roadboard or piece of flagging tape across the entrance to a drift, stope or other opening, the mine rescue team will have effectively established the shortest route to them if they run into trouble. This method also prevents other mine rescue teams from entering areas that are not associated with the mine emergency or that have already been examined.

Drifts, Stub Ends And Doors

When a mine rescue has examined a drift end, room with a door or farthest point of travel, the area must be marked with the mine rescue team number, time and date. This will indicate to the next team how far the previous team advanced during an exploration trip. The next team in the mine can resume activities from that point and not waste time examining areas that have already been explored.

8.8 Link Lines

Link lines are ropes approximately six feet in length that are equipped with snap lock fasteners on each end or one end may be permanently attached to a “D” ring miner’s belt. The other end of the link line is to be attached to a stretcher or to another link line or person. Link lines must be used as soon as slight smoke is encountered or if travel conditions require mine rescue team members attach to the stretcher or each other. As a matter of good practise, the captain should always be linked to the stretcher.

8.9 Stretcher Procedure

Most mine rescue teams travel with a stretcher that is used to transport goods and materials or to transport ill or injured people. Although a stretcher is handy for transport, it is not essential to carry during a mine rescue mission.

When mobile equipment is used during a mine rescue mission the use of a stretcher is not necessary unless there is someone in the mine who is injured.

When a stretcher is used during a mine rescue mission, the captain must be at the front of the stretcher and the vice captain at the back end. The location of the other team members around the stretcher is discretionary, however it is important to consider the size and strength of the stretcher bearers and ensure the distribution of weight and balance is equal.

During a mine rescue mission it is important to rest the team periodically to change the stretcher bearer's handgrip, and position on the stretcher. The purpose of changing positions around the stretcher is so the carrying hand alternates between the right and left allowing each hand to rest between changes. When a person is being transported in a stretcher, two-thirds of the patient's body weight is situated in the head and torso; therefore it is also important to change position from front to back or back to front of the stretcher during transport.

Whenever possible, a casualty should be placed in a stretcher so their head is at the front end of the stretcher. Placing the casualty in this position allows the captain a better opportunity to examine the casualty en-route to the fresh air base and allows the vice / co – captain to observe the casualty while travelling.

Suggested Stretcher Content

- Blankets
- Brattice or plastic sheeting
- Wedges
- Hammer & nails
- Stapler
- Scaling bar
- Saw with guard
- Spare oxygen cylinder
- Slide staff
- Shovel or grub hoe
- Team self rescuer (1 minimum)
- First aid kit
- Rescue breathing apparatus for casualties
- Fire extinguisher
- Axe with guard

Other items as may be appropriate but mine rescue teams must not carry materials or equipment that are unnecessary.

8.10 Stretcher Drills

This procedure is set up for a five person team. If the team is comprised of 6 persons the Vice / Co – Captain will not carry stretcher but will move behind the stretcher and the sixth person will assume the #5 position.

#1 Captain	Front of the stretcher
#2	Left front side
#3	Right front side
#4	Left rear
#5	Right rear

8.10.1 Changing Sides

1. Captain stops the team
2. Team lowers the stretcher to the ground
3. #2 and #3 switch sides. Both step up in front of the stretcher but behind the Captain. #3 stays close to the stretcher and #2 steps around outside of #3.
4. #4 and #5 switch sides. #4 stays close to rear of stretcher and #5 steps around outside of #4.
5. Team members kneel in position. When the Captain raises the baton the team will lift the stretcher together.
6. Captain gives the command to advance and waits for response from Vice / Co – Captain prior to advancing.

8.10.2 Advance Single File

1. Captain stops the team.
2. #3 stands in front of the stretcher facing the direction of travel.
3. #2 steps to the side of the stretcher.
4. #5 steps to opposite side of stretcher.
5. #4 steps to rear of stretcher.
6. #2 and #5 pick up stretcher and place in hands of #3 and #4.
7. #3 and #4 grasp the stretcher. #3 and #4 give the stretcher a shake to indicate they are in control of it.
8. #2 falls in behind the Captain.

9. #5 falls in behind stretcher and #4.
10. Captain gives the command to advance and waits for response from Vice / Co – Captain prior to advancing.

8.10.3 Return to Four Man Stretcher Carry from Single File

1. Captain stops the team.
2. #2 and #5 take positions on opposite sides of the stretcher.
3. #2 # #5 gives the stretcher a shake indicating that they are in control of it.
4. #5 will give the command to lower the stretcher.
5. Team members return to and assume resting position for four person carry.
6. Captain gives the baton signal to raise the stretcher.
7. Captain gives the command to advance and waits for response from Vice / Co – Captain prior to advancing.

8.10.4 "Circle The Wagon"

This procedure allows for stretcher carriers to change hands and positions on the stretcher while continuing in the same direction. Allows for rest of hand and arm when carrying a patient or heavy unbalanced.

1. Captain stops the team.
2. Team lowers the stretcher to the ground.
3. Captain gives baton signal (baton waved in clockwise position over the stretcher) or a voice command "Circle the Wagon".
4. Team moves around the stretcher in a clockwise direction. #5 stops at the #2 position, #4 at # 3, #3 at #4 and #2 at #5.
5. When repositioned assume resting position.
6. Captain gives the baton signal or voice command to raise the stretcher.
7. Captain gives the command to advance and waits for response from Vice / Co – Captain prior to advancing.

8.10.5 Reverse Direction – Captain Leading Stretcher

1. Captain stops the team.
2. Team lowers the stretcher to the ground.

3. Captain gives baton signal (baton waved in clockwise circle over his head), voice command or horn signals to reverse direction.
4. Team moves around the stretcher in a clockwise direction and when repositioned assume resting position.
5. Team now faces new direction of travel.
6. Captain gives the baton signal or voice command to raise the stretcher.
7. Captain gives the command to advance and waits for response from Vice / Co – Captain prior to advancing.

8.10.6 Reverse Direction Quickly Vice / Co – Captain Leading

1. Captain stops the team.
2. Captain gives the distress signal 4 whistles.
3. Captain turns and gives horn signal to reverse 3 whistles or baton signal (baton waved in a circle and cut through the center).
4. Team members turn bodies into stretcher, change direction which changes carrying hands on stretcher.
5. Team advances in opposite direction quickly until halt signal given by Captain (when the team is safe).
6. Team lowers stretcher and assumes resting position.

8.11 Size Of Mine Rescue Teams

In the province of Manitoba, a mine rescue team must be no less than five persons. If circumstances dictate and there is the availability of personnel, six or more people could make up a team.

Although a mine rescue team normally consists of 5 or 6 persons, there are situations where a team consisting of three or four persons may be acceptable. The decision to deploy a three or four person team must be carefully examined and approved by senior management & rescue co-ordinators.

Should a three or four person team be used, there **must be** adequate provisions made for **back-up** and **reserve** rescue personnel. Under no circumstances should these provisions be omitted.

Consideration should be given to use a three or four person team only after the following conditions have been reviewed and found acceptable:

(1) There is a back-up team consisting of at least the same number of members as the team that will be in the field.
(2) Time is of the utmost importance, whereby a life is at stake and a successful rescue could be accomplished by three or four people.
(3) The mine rescue team will not be travelling in unfamiliar areas of the mine.
(4) The travel conditions are good and the distance to be travelled is short.
(5) The work to be performed is not too strenuous.
(6) The duties to be performed can be done with minimum risk.
(7) The assembling of full teams would consume too much time thereby allowing a mine emergency to reach major proportions and place lives in needless jeopardy.
(8) Each three or four person team will contain at least one person who is well qualified at mine rescue principles and procedures.
(9) All other risk factors have been carefully examined before deploying a three or four person team.

8.12 Role Of The Mine Rescue Team Captain

The team captain must assume the role of "leader" and take charge of and be responsible for, the discipline, safety and work performed by the members of the mine rescue team. The captain will report to and take direction from the director of operations or their delegate.

8.12.1 Preparing To Go Into The Mine

Prior to commencing an emergency response mission the captain must assess the mental and physical condition of each member of the team. If a team member is deemed unsuitable for a mission, the captain must not allow them to participate. People considered unsuitable for a mission may be utilized to fulfil some other function.

Prior to entering the mine;

(1) Each team member must inspect and conduct the necessary tests to

ensure their breathing apparatus is suitable for use.

(2) All equipment is checked and is certified, suitable for use.

(3) Information about the mine emergency is clearly communicated to all members of the mine rescue team.

(4) Mission instructions are clearly understood.

(5) Watches are synchronized.

(6) Ensure stretcher and its contents are tested and loaded.

(7) Ensure mobile equipment has been examined and certified, suitable for use.

(8) Ensure all necessary maps, writing instruments, route of travel markers etc. are available for the team.

(9) Once team members are under oxygen, ensure each person is inspected to ensure:

- Head straps are not twisted and are properly tensioned.
- Miner's lamp is functional.
- Facepiece on straight, properly tensioned, check seal on facepiece, breathing tubes not kinked, bayonet rings locked on centre connector / plug-in coupling and locked on apparatus.
- Breathing apparatus harness is undamaged and properly secured on the team member.
- Oxygen cylinder has adequate pressure, is open full and the valve has been backed off ½ turn.
- Oxygen gauge is functional and cylinder pressure has been recorded.
- Ensure apparatus cover is secure.
- Vice-captain to ensure Captain's apparatus is checked.
- Ensure signal devices such as horns or whistles are functional.
- Perform final examination of stretcher and any equipment travelling with the team.
- Report to the person in charge of the emergency response mission.

- Conduct the necessary ventilation and gas tests to determine the conditions at the shaft collar or portal entry, exhaust raises.
- As appropriate report significant findings to the person in charge of the emergency response mission.

(*Note: The use of contact lenses is acceptable in Manitoba but members must realize that in wearing contacts, they may have some pain or discomfort if the contacts dislodge while under O_2 and this could jeopardize the mission.)*

(10) Begin the mission.

8.12.2 Conduct In The Mine Environment

The following procedure guidelines have been developed to assist mine rescue teams when they are engaged in an emergency response mission:

(1) Conduct ventilation and gas tests on a frequent or as required basis. Ensure all intersections are tested.

(2) Record, on a mine plan all unusual or abnormal conditions encountered during the mine rescue mission.

(3) Mark route of travel, sign and date doors, drift walls, stub ends and farthest point of travel.

(4) Feel all doors before opening them.

(5) Unless otherwise directed, leave all ventilation control doors as found.

(6) Shortly after entering contaminated air, stop the team, take necessary ventilation tests and check each team member's breathing apparatus and each team member to determine their mental and physical readiness to continue.

(7) When carrying a stretcher, change the positions of the team members at regular intervals.

(8) Fasten link lines before entering a contaminated area.

(9) Rest team periodically and especially after conducting a work assignment.

(10) Check pressure gauges and record pressures at least every 15 – 20 minutes.

(11) Approach falls of ground or unstable ground with extreme caution.

(12) Do not remove deceased persons from the mine unless directed to do so.

(13) Evacuate trapped or injured mine personnel as soon as possible. Or as practical to do so.

(14) Carry out the orders given by the emergency response control centre, to the best of your ability.

(15) Ensure the mine rescue team returns to the fresh air base on time, even if the work assignment was not completed.

8.13 General Mine Rescue Emergency Response Procedures

(1) Exploration or other work ahead of fresh air base should not be attempted with less than a five person team. *(See three or four person team exceptions).*

(2) Team members are not to separate from other members of the team, unless there is some compelling reason to do so and only if it does not place the team or team members at unnecessary risk. Criteria to allow the split could include circumstances, visibility, communications, and knowledge of the areas that the team is working in.

(3) If a team is not familiar with the mine workings they need to request a guide or person familiar with the mine. This may be a person from another team who is familiar with the mine or it may be a supervisor who is mine rescue trained. This person will assume the number 2 or 3 position to help direct the team through the mine.

(4) A fully equipped back-up mine rescue team of not less than five persons should be kept in readiness at all times at the fresh air base while exploration or other work is in progress ahead of the base.

(5) Mine rescue team members must maintain their core competencies, keep physically fit and be ready and able to respond to an emergency if called upon.

(6) The team captain and team members should follow as nearly as possible, the directions given by the emergency response control

centre.

(7) Team members should respect the authority of the team captain and follow orders as directed.

(8) If a team member becomes disabled or distressed for any reason, the team must treat that person as a victim and transport them to the fresh air base without undue delay.

(9) Upon receipt of a distress signal or call, the back-up team should proceed immediately toward the distress call location and take whatever action is necessary to address the situation.

(10) Mine rescue personnel should not eat rich or heavy meals before wearing breathing apparatus. Minimum 1 hour prior to wearing unit.

8.14 Duration Of Mine Rescue Mission

The Oxygen breathing apparatus in use in Manitoba are a 4 hour duration unit. As a matter of safety the units and members use a 2 hour time limit. This time limit may be extended by requesting an extension from the Director of Operations.

The DO will assess the situation and grant the team an extension or will order the team out and send the back up team to take over the mission. Some of the factors used to make this decision may include;

- O_2 cylinder pressures when mission began.
- Method of travel and condition of team.
- Conditions encountered.
- The type of mission that the team is working on.
- Are there people at risk?

Another important factor in determining the duration of the mission is the team's oxygen consumption on the trip into where the problem may be. The rule of thumb is that you need to have twice the amount of Oxygen to get back out to the FAB as it took to get to where the team is. This is the direct route not counting any side trips. The lowest bottle reading will govern the decision of how much Oxygen has been used and is needed for the return trip. For example if it took 20 bar of oxygen to get to your (direct) destination, you should then allow 40 bar for your return trip.

Another rule of thumb is time. You allow twice as much time to get out as it took to get to where you are. This again is the direct route taken to get there.

In extending the mission time it is important that the decision is made mutually between the Captain and the Director Of Operations.

8.15 Care Of Personnel Found In The Mine

When injured personnel are found in the mine they must be given proper first aid treatment and if required the necessary breathing apparatus to ensure their safety. If an injured person is found in a dangerous environment, life saving efforts must take precedence over first aid treatment. If they are found in a dangerous atmosphere, breathing apparatus should be supplied to them and, if possible, they should be moved to an area of good air as soon as possible. Injured personnel should be transported to the fresh air base if it is safe to do so. If they are in danger, they should be isolated in an area where the risk will be minimal. Refuge stations or other safe location may be used as a temporary haven.

If the mine rescue team provides breathing apparatus for people found in the mine, they must instruct them how to use it. If a victim is left with a piece of breathing apparatus, they must be absolutely certain that the person knows how to use the apparatus and will not move away from the location where the mine rescue team has left them.

The location of all workers should be identified on a mine map and reported to the emergency response control centre.

It may be necessary to physically restrain irrational persons to prevent them from injuring themselves. Persons who are not irrational should never be tied up or otherwise restrained.

When personnel are being brought out from the mine, they should be carried in a stretcher or placed in between team members and closely monitored until they have been secured in the fresh air base or are on surface.

8.16 Mine Rescue Work Utilizing Mobile Equipment

CAUTIONARY NOTE: **DIESEL ENGINES** will function with decreasing power in atmospheres where the oxygen level is as low as 16%. Turbo charged engines will operate with oxygen levels down to 11%.

Source: Detroit Diesel.

When great distances have to be travelled during rescue work, the use of mobile equipment may be required. Although this solves the problem of distance, it raises other questions that must be addressed before deploying a mine rescue team in motorized equipment.

Generally speaking, the conditions that a mine rescue team encounters in the mine will determine what mode of travel to utilize and what procedures to follow. In any event, a decision to utilize mobile equipment during a mine rescue mission must be carefully examined before proceeding.

8.17 Guidelines For The Use Of Personnel Carriers During A Mine Emergency

The following guidelines shall be followed for the use of mobile diesel equipment / personnel carriers:

- The team must use two vehicles.
- Vehicles must be capable of carrying the whole team in the event that one of the units breaks down.
- Operators must be qualified and competent to operate the vehicles that are being used. (Familiar with the vehicle)
- Operators must perform the pre-use inspection for the vehicle.
- Captain and Vice Captain should not travel in the same vehicle. Captain's vehicle will lead the mission. Captain and Vice Captain must not drive.
- Minimum of two passengers per vehicle.
- Communications between vehicles are very important. Communications to the Director is vital. The D.O. must know where the team is. If the team is not using two way radio communications, predetermined locations for communication should be set out prior to team leaving fresh air base.
- Travel in fresh air with good visibility is recommended.

- Travel in limited visibility is not recommended. Travel in limited visibility may be done only after careful consideration and assessment of the situation is made between the Captain and D.O.
- Continuous gas monitoring must be done and recorded on the Captain's log sheet or map.
- Vehicles must not be used in atmospheres that may be explosive.

It is important to note the progress and distance travelled in the vehicles. This is to keep in mind the distance that the team may have to walk to the FAB if the vehicles should break down or need to be abandoned because of heavy smoke or some other obstruction.

Experience has shown that the use of personnel carriers to transport teams in a mine rescue mission greatly benefits the situation. Time saved on breathing apparatus usage, keeping the team in good condition to do the work required to solve the problem at hand are major benefits for use of personnel carriers.

It is important to remember careful planning and constant communications are vital to maintain the **SAFETY OF THE TEAM**.

Team members must train driving or operating a light truck or personnel carrier while wearing their Oxygen breathing apparatus. Members must be comfortable, know how it feels to operate using breathing apparatus and know the limitation of operating this way in order to complete the mission safely.

8.18 Using Shaft Conveyance Without Communications

If during a mine emergency the communications systems or shaft signal system go out of service and a mine rescue team is in the mine, the following procedure shall be used.

The hoist person will take the shaft conveyance to the last level that the team got off on. They will spot the cage there for two (2) minutes and then will leave the level and return to surface. They will wait on surface for two (2) minutes and return to the level the team is on. This procedure will be continued until the hoist person receives word that the team has returned to surface.

Caution must be exercised by the team if the conveyance is at the level when they enter the station. If the conveyance is there, the team must not enter the conveyance as they will not know how long the conveyance has been parked there and it could start to leave

the level with the team partly in the conveyance. They must wait until it returns to the level the next time. **SAFETY OF THE TEAM IS OF UTMOST IMPORTANCE**.

8.19 Communications For Mine Rescue

Phone and radio communication requires some of the same basic techniques. Transmitting a clear message to accurately describe a scene or make a request is vital to effective communications. Listed below are some guidelines taken from the "Essentials of Fire Fighting IV" and personal observations.

- Use a moderate rate of speaking not too fast or slow. Designed for easy understanding. This includes not using phrases such as *"ah"* or *"uhm"* during the dispatch.
- Use a moderate expression in speech, not monotone and not overemphasized but use carefully placed emphasis. Avoid anger or shouting over the radio and be careful to articulate properly. Strive for the correct pronunciation of words.
- Use a vocal quality that is not too strong or weak. Finish every comment and avoid a voice that trails off towards the end of the transmission. Keep the pitch in a midrange not too high or too low. Avoid dialects or regionalisms in transmissions, and strive for a good voice quality.
- Keep things such as gum and candy out of the mouth. Be confident in what you say, and position the microphone appropriately to make the best use of the system. Wearing a face piece will distort the quality of the transmission positioning the phone or radio close to the speaking diaphragm is important.
- Be concise and to the point, don't talk around the issue and give the information required in a logical and complete manner that best addresses the service requested.
- Using enough words, but not too many that best describes the situation. Transmit only essential information
- Background noise will make understanding a transmission very difficult, if possible remove the noise or remove yourself to a quieter area.
- If you have to transmit the information, keep it brief and have the receiver repeat the information.
- Do not transmit until airwaves are clear
- Think about what is going to be said before transmitting.

- If the director of operations or the team captain needs a moment to think of a response, let the other know to stand by for the response.
- Never use profane or obscene language on the air or the phone.

There are three basic rules when using radio or phone transmission:

1. Identify yourself when transmitting, use team #, or captains name.
2. Repeat the essence of the message to the sender (echo).
3. Let the receiver know you have completed your transmission by saying “over”.

Mine rescue teams need to be aware of the fact their radio transmissions are most likely being monitored by personnel in the refuge stations. In fact some phones are on the same line and the conversations with the director can be monitored. Reporting conditions may cause confusion if employees in the refuge stations don’t fully understand what is happening in the mine. For example employees in the refuge station hear a transmission from the mine rescue team that “conditions are clear” they might assume the emergency is over and try to leave the refuge station, when actually the team is reporting on conditions in a small part of the mine. The procedures and training should address with all employees the importance of the communications system. Monitoring the emergency channel on the radio should be discouraged. Attempting to use the radio or phones to get an update of the emergency should also be discouraged.

Sensitive issues during a mine emergency should be communicated via a secure line. If the emergency becomes fatal, the names, and locations of those found should be communicated to the director of operations via a secure phone line.

Mine phones and radio systems are extremely important to mine rescue and mine operations. Maintaining both systems to function correctly is very important. There are times when this is not possible. Information about a phone that is not working or a section of leaky feeder cable that is damaged needs to be passed on to the mine rescue team at the briefing.

Using a person in the refuge station to relay to the director becomes difficult if lots of information is being sent. Give the conditions of the team and the area that was explored since last contact. Try to minimize the amount of information that being relayed to the director. If plenty of information needs to be given to the director give

little bits at a time so the person relaying doesn't forget the message or confuse the information.

8.20 Specialized Procedures For Non-Emergency Mine Rescue Activities

Although the primary purpose of mine rescue capability is to respond to mine emergencies, mine rescue personnel are often required to provide other services. Blast clearing, exploring old mine workings, gas testing, simulated emergencies, etc. are just some of the non emergency mine rescue personnel may be involved with.

Since the Mine Rescue Instructor is the closest link with mine rescue personnel, mine rescue instructors are to be involved in the planning process when mine rescue personnel are being considered for non-emergency activities. It is also recommended that written standards and procedures be developed for non emergency activities that are repetitive in nature.

8.21 Review Questions

1. What is the prime consideration of a mine rescue team?

2. What is the main consideration to be observed by a team captain when carrying out a mine rescue operation?

3. When the mine rescue personnel arrive at the station what tasks should they be completing?

4. What are the fundamental principles of Mine Rescue?

5. What should the director of operations consider when making his plans?

6. What are some conditions that can govern the rate of travel of a team?

7. When the mine rescue team is in the mine who must the team follow for direction?

8. What is the ultimate responsibility assumed by the Captain of the mine rescue team?

9. If necessary can a team transport a victim through unexplored territory? If so, how is the decision made to allow the movement?

10. What four guidelines are to be considered when passing through ventilation doors or stoppings?

11. How must doors be left after passing through them?

12. If your team must change the position of door other than the way you found it, who will make that decision?

13. What situations should the Captain rest and check the team?

14. What situations must the Captain rest and check the team?

15. When the Captain asks for a team check what is the purpose of the checks?

16. When a rescue team uses a horn to signal with when wearing apparatus, what is the signal codes in Manitoba?

17. What is the best route of travel during an emergency and why?

18. In mine fires it is necessary to employ rescue teams unfamiliar with the workings, therefore, it is advisable for the mine to provide a trained supervisor. What position should they take?

19. Why is it good for you to mark your course of travel even in today's mines with the size they are?

20. What methods can be used for marking route of travel?

21. What is the normal length of a link line?

22. When carrying a patient in a stretcher, why should their head be forward, in the direction of travel?

23. Who will make the decision to send a three man team into the mine during an emergency?

24. The normal number for a team entering into a mine emergency is 5 or 6. If a 3 or 4 person team must be sent in, what considerations must be reviewed prior to deploying the 3 or 4 person team?

25. Should a team ordinarily be sent ahead of a fresh air base without a standby team?

26. Prior to entering the mine with the team, the Captain must complete a number of duties prior to going U/G. What are these duties?

27. Once the team is under Oxygen, the captain needs to check team members prior to entering the mine. What checks need to be done?

28. When going by drifts, X - cuts or raises what should the team do?

29. What is the main responsibility of the Captain?

30. If your team must separate, what guidelines must be followed?

31. If a team member is having trouble with his apparatus, should they be sent out of the mine?

32. What should a team captain do if a team member becomes excited or panicky?

33. What factor determines the amount of time a team may be away from the fresh air base?

34. When determining the time that you have left to remain in the mine and travel time required, what is the factor you use?

35. If you start into the mine with a fully charged oxygen cylinder and 30 bar of oxygen is used getting to the work area, how much oxygen should be in the cylinder when you start back to fresh air?

36. With respect to mine rescue teams evacuating personnel from a mine emergency, how must that person be dealt with?

37. What are two important benefits of using mobile equipment in a mine emergency?

38. What criteria should be considered regarding the use of mobile equipment by mine rescue teams?

39. How long will the cage remain on the level when communications or signalling system is not working?

40. What is the procedure used when the signalling system for the cage is not operable?

41. What method should be used when communicating over the mine radio system?

42. Mine rescue personnel are involved in non-emergency activities at times. How should these activities be handled?

LEARNING OBJECTIVES AND TARGET AUDIENCE

SECTION 9
SPECIAL PROTOCOLS, PROCEDURES & PRACTICES

Learning Objectives

Section 9 is intended to cover miscellaneous information about protocols and practices that are used in mine rescue but do not fit in with any of the previous sections.

Suggested Target Audience

Section Number	Topic	Basic Mine Rescue Trainees	Standard Mine Rescue Trainees	Advanced Mine Rescue Trainees	Mine Rescue Equipment Technicians	Mine Rescue Instructors	Director of Operations & Resource Personnel	Senior Management Personnel	Supervisors	New Or Transferred Employees
9.1	Post Incident Stress	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
9.2	Critical Incident Stress Management	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
9.3	Recognizing Critical Incident Stress	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
9.4	Dealing with Critical Incident Stress	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
9.5	Air Lifting Bags	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
9.6	Electronic Gas Detection – How Does It Work?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**				
9.7	Review Questions	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			

Section 9. Special Protocols, Procedures & Practices

9.1 Post Incident Stress

During an emergency when response workers and managers are working to resolve the problem, our bodies produce adrenaline and other biochemicals to help us operate at peak efficiency. It's part of our body's automatic fight or flight response. After the emergency is over there are often some of these chemicals left in our systems. In addition our bodies may have used up valuable stores of the chemicals and minerals it requires to work efficiently. This can cause a wide variety of reactions. We may feel; wound up, agitated, depressed or anxious. There may be feelings of unrealness of being disconnected or we may even feel numb or drained. This is usually nothing more than the effects of our bodies chemical emergency response system or the by-products of those bio-chemical reactions still running around in our bodies.

The most effective method to deal with post incident stress is to exercise and eat well. It is a simple matter of operating our machine (body) to work all of the contaminants through the system. Exercise will help burn off left over adrenaline etc. and speed up the removal of contaminants from the cells of the body. Exercise also releases endorphins in the brain, which makes you feel better. Eating foods high in vitamins and minerals will replace the body's supply of the chemicals it requires to run efficiently.

Healthy social interaction with friends or family will also help your mind and body get back to normal operations.

Failure to effectively deal with post incident stress can contribute to the onset of critical incident stress.

9.2 Critical Incident Stress Management

When an incident occurs involving death, serious injury, or emergency in a potentially hazardous environment, mine rescue personnel are often called upon to help.

A critical incident is an event, which is outside the range of usual human experience and is psychologically traumatic to the person.

During these missions mine rescue personnel may be subjected to situations that have the potential to overwhelm the capacities of a person to cope psychologically with the incident. Mine Rescue personnel should be aware that they could experience strong emotional reactions, which has the potential to interfere with their ability to function at

the incident or later.

Mine Rescue personnel should be aware that critical incident stress debriefing is available and should be requested if incidents past and present become a source of mental or physical discomfort.

9.3 Recognizing Critical Incident Stress

Critical incidents may produce a wide range of stress reactions, which can appear immediately at the scene, a few hours later or within a few days of the event. Stress reactions usually occur in four different categories: cognitive (thinking), physical (body), emotional (feelings), and behavioral (actions). The more reactions experienced, the greater the impact on the individual. The longer the reactions last, the more potential there is for permanent harm.

The following are some samples of stress reactions that can show up after a critical incident:

- Cognitive (Thinking)

Poor concentration	Memory problems
Poor attention span	Difficulties with calculations
Difficulty making decisions	Slowed problem solving

- Emotional (Feelings)

Loss of emotional control	Grief
Depression	Anxiety/fear
Guilt	Feeling lost/overwhelmed

- Physical (Body)

Muscle tremors	Chest pains
Gastro-intestinal distress	Difficulty breathing
Headaches	Elevated blood pressure

- Behavioral (Actions)

Excessive silence	Unusual behaviors
Withdrawal from contact	Sleep disturbance
Changes in eating habits	Changes in work habits

What may seem to be unusual reactions often are just normal responses to an abnormal situation.

9.4 Dealing With Critical Incident Stress

Most critical incident stress symptoms are expected to subside within 3 to 4 weeks of the incident. Within that time it can drain you both physically and mentally.

The same mechanisms for coping with post incident stress are effective with critical incident stress.

The more you talk about the incident the easier it will get. Avoid any temptation to withdraw into a shell. Interact with others as normally as possible. Stay active and involved. People do not have to understand in order to care.

Get back into your regular routine as soon as possible.

Eat at regular meal times even if you don't feel like it. Eat good balanced meals. Avoid alcohol, drugs, coffee, tea, sugary foods and cafinated soft drinks. These things may make you feel better momentarily but will agitate your nervous system and do more harm than good.

Get some vigorous exercise within 24 hours of the event. Exercising regularly will help you manage residual stress in the following weeks.

Do not get obsessed by the incident. Avoid the temptation to over analyze the event or your part in it.

Remember there is specially trained people that help emergency personnel deal with critical incident stress. If you feel that you are having any of these symptoms after a critical incident, talk to your coordinator. He will have contact people to help you get through the situation. Don't feel that you are too macho and that you don't need help.

Critical incident stress debriefings are always conducted with the utmost regard for the individual and strictest confidentiality.

9.5 Air Lifting Bags

Note: *These instructions for use do not apply to the NT Res Q Bags manufactured by Res Q Tek Inc. If your station has these lifting bags refer to the manufacturer's instructions for use.*

Air bags are a multi-purpose portable inflation system that can be used to lift and displace heavy rigid objects.

They are normally used in emergency situations such as structural collapse and containment, vehicular extrications, industrial entrapment and excavation collapse. Since air bags do not have any spark producing parts, they can be used in an explosive atmosphere.

The common systems available are Vetter, Maxiforce, Holmatro and MatJack. The information that follows is general in nature. For specific information on the use, care and maintenance of the equipment always refer to the manufacture's instruction manuals for the type of air bags the Mine Rescue Station is using.

9.5.1 System Components

The basic air bag system consists of six components:

1. Air source

   The most common air source is that found with a SCBA compressed air bottle. Other sources may be adapted to use with the system but it must be noted that it is best to use a dried air source to prevent damage to the bags. (Refer to the manufacture's user manuals for complete details).

2. Pressure reducer or regulator

   Regulators are available to reduce the supply air pressure from as much as 5,500 psi but the standard regulator is designed for use with air inlet pressure of up to 3,000 psi.

   These regulators are self-contained, direct acting, pressure reducing, diaphragm regulators and utilize spring loading to balance the outlet pressure and thereby reduce the effect of, the decreasing of or variations in the inlet pressure. The regulators are normally

designed to be used with a SCBA air cylinder.

3. Controller

   Controllers are equipped with quick disconnect hose fittings on the inlet & outlet, a pressure gauge to monitor the pressure applied to the air bag, valves to apply and release the air pressure to the bag, and a relief valve usually set at 118 to 124 psi.

   These controllers may vary, with valves that may be the turn-on – turn-off type, push button or joystick “deadman” type. The controllers may be set up to control one bag or a dual control system to control the operation of two bags at once.

4. Interconnecting hoses

   All hoses are equipped with a quick connect style of coupling. Hoses are available in different colours and when using more than one bag, different colours of hose should be used to each bag for ease of identification.

   All hoses should be rated at a working pressure of at least 300psi.

5. Air bag

   The air bag is usually made from a molded “rubber” type of material and is reinforced with steel cable or Kevlar. They are equipped with a male half of the quick connect hose coupling.

   A common type of bag is made with neoprene reinforced with six layers (3 per side) of Kevlar reinforced material for strength and rigidity, even at their full inflation pressure of 118 psi. All air bags incorporate non-slip, molded surfaces designed for maximum friction and holding capacity. Units now have a bright coloured X on them to make it easier to position them correctly.

   Each bag is proof tested at twice the operating (full inflation) pressure and has a minimum burst pressure of four times the operating pressure.

6. In line shut off valve with relief

   The in-line shut off/relief valve is designed to keep air bags fully and properly inflated when the air supply source is:

   - Disconnected from the controller.
   - When excess pressure must be automatically relieved due to shifting loads and for temperature changes.

   The shut off/relief valve consists essentially of an air inlet and outlet with the quick connect hose fittings, a shut of valve to isolate the associated air bag. The relief valve is an internal, non-adjustable spring-loaded mechanism to relive the air bag pressure when it exceeds 135 psi.

9.5.2 System Operation

An air bag system operates functionally as follows:

- After the air bags are properly positioned or placed the air source is turned on.
- High pressure air is reduced to 130 psi and flows to the control valve through the connecting hose.
- The valves on the controller are operated to allow air to flow to one or two air bags to allow for the controlled lift or displacement or the load.
- In the line between the controller and each bag is an inline shut-off and relief valve to allow for isolation of the bags from the controller and to allow any excess air pressure to be relieved from the air bag.
- As air flows into the bag, it increases in height resulting in a corresponding lift/displacement. Maximum lift/displacement occurs at approximately one inch of inflation height (minimum reduction of the air bag cross section). *See section on the effect of surface contact Section 9.5.3.*
- When finished with the operation of the air bags, the air supply is turned off. Bleed off the residual air pressure through the controller. Disconnect the system components, clean and inspect prior to being stored for future use.

It is important for the person operating the controls of the air bag system to pay attention to the gauges, not the lift and to take orders only from the captain or the person designated to give orders.

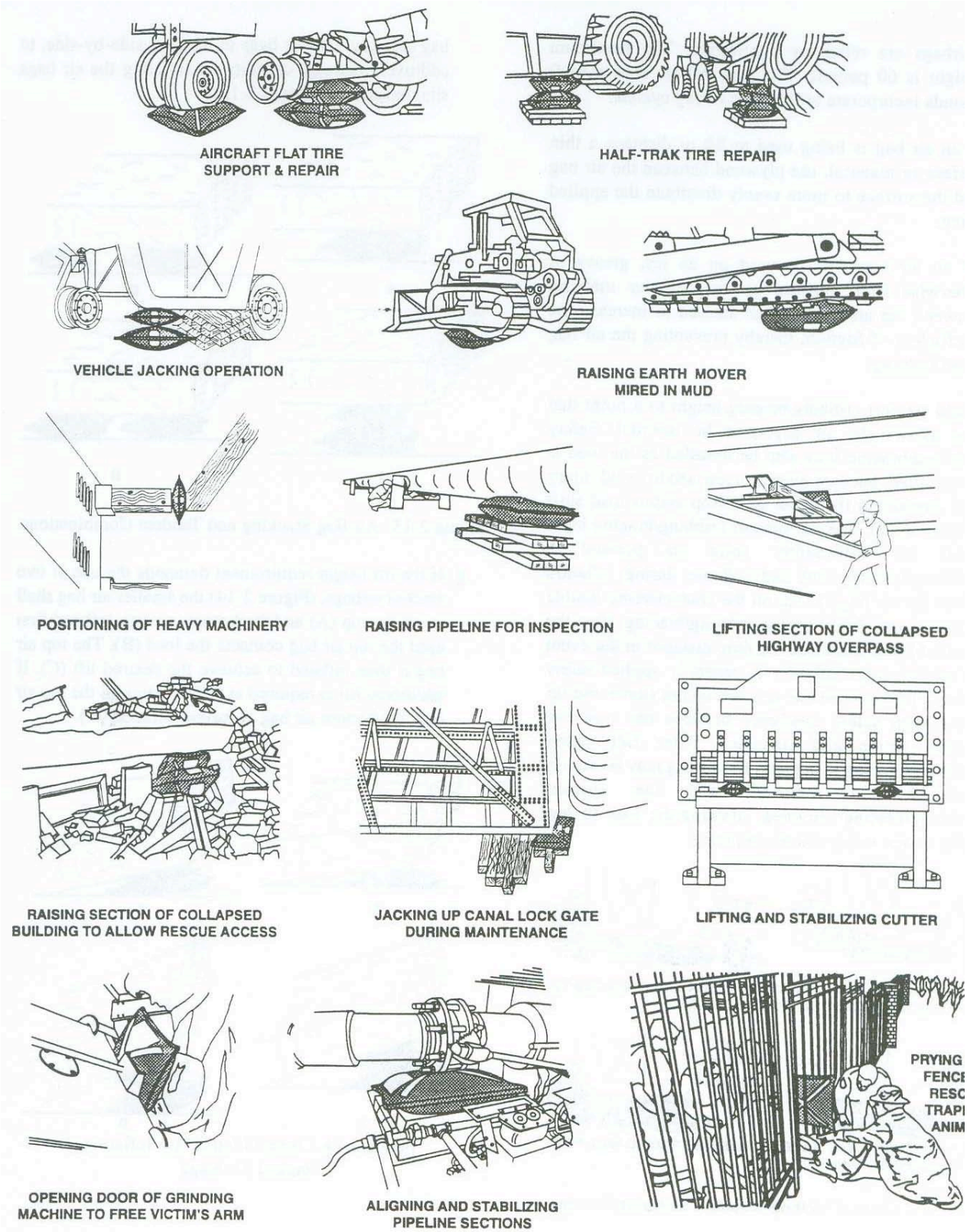
AIRCRAFT FLAT TIRE SUPPORT & REPAIR
HALF-TRAK TIRE REPAIR
VEHICLE JACKING OPERATION
RAISING EARTH MOVER MIRED IN MUD
POSITIONING OF HEAVY MACHINERY
RAISING PIPELINE FOR INSPECTION
LIFTING SECTION OF COLLAPSED HIGHWAY OVERPASS
RAISING SECTION OF COLLAPSED BUILDING TO ALLOW RESCUE ACCESS
JACKING UP CANAL LOCK GATE DURING MAINTENANCE
LIFTING AND STABILIZING CUTTER
OPENING DOOR OF GRINDING MACHINE TO FREE VICTIM'S ARM
ALIGNING AND STABILIZING PIPELINE SECTIONS

Figure 9.1 Typical Uses For Lifting Bags

9.5.3 Effect Of Surface Contact On The Lifting Capacity Of Air Bags

Air bags have an advantage over other lifting devices such as hydraulic jacks because they have no moving parts, are capable of lifting heavy loads, and are relatively thin (approximately 1¼ inches thick). The biggest advantage is they can be used in situations where a conventional jack will not fit.

The air bags work on a simple yet proven physical formula:

The pressure of the air being forced into the bag **(in PSI)**	X	The area of the bag in contact with the load **(in sq. in.)**	=	Lifting Force **(in pounds)**

1.5 Through 72.3 Ton Capacities

Model Number	Cap. (tons)	*Max. Lifting Hts. (in)	Bag Dimensions (in)			Air Req. @118 PSI (Cu. Ft.)	Max. Burst Pres. (PSI)	Wgt. (lbs)
			Length (in)	Width (in)	Thick (in)			
B1	1.5	3.4	6	6	.6	.14	700	1.1
B3	3.2	3.9	6	12	.6	.35		2.2
B5	4.8	5.6	10	10	.6	.77		3.1
B8	7.6	7	12	12	.6	1.8		6
B10	11.4	7	18	12	.8	2.5		9
B12	12	8.2	15	15	.8	3.0		8
B17	17	9.2	21	15	.8	4.9		11
B22	21.8	11.1	20	20	.8	7.3		15
B28	27.6	12	20	26	.8	11	600	19
B32	31.8	13.2	24	24	.8	13.8		21
B35	34.7	9.8	42	15	.8	11.7		22
B44	43.8	15.5	28	28	.8	21.6	475	29
B55	55	17.2	32	32	.8	34		40
B74	72.3	20	36.6	36.6	1	47		60

All Maxiforce Air Bags have a maximum working pressure of 118 PSI.

Figure 9.2 Lifting Capacity Chart (Maxiforce Bags)

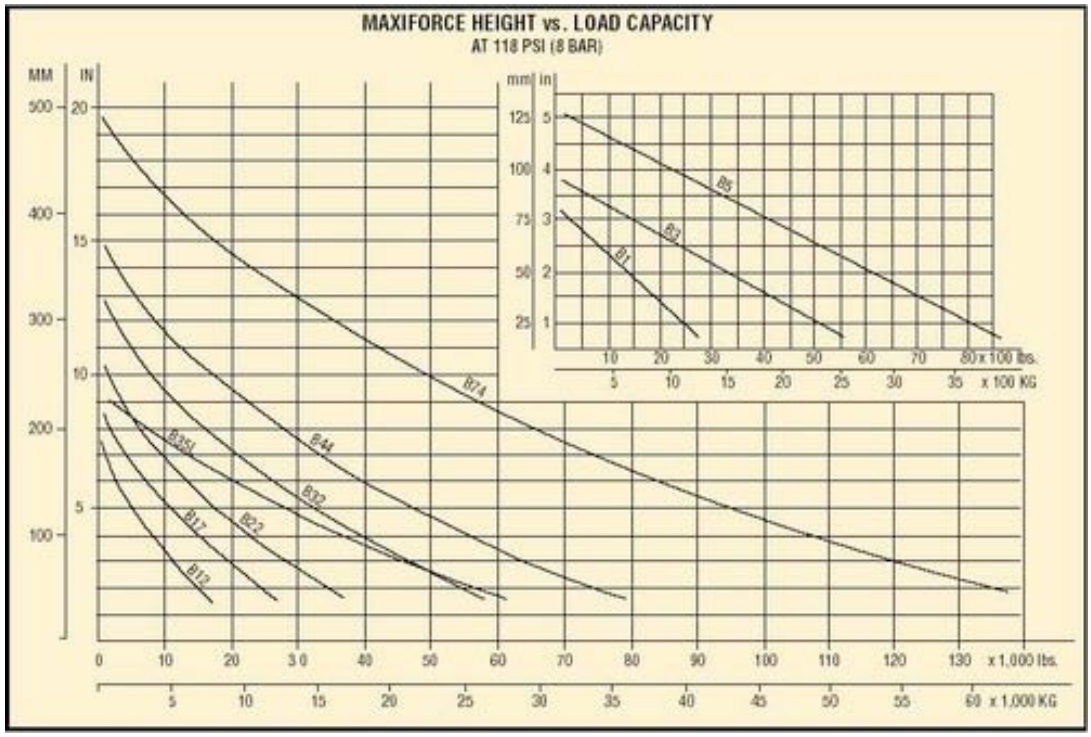

Figure 9.3 Lifting Height Compared To Load Capacity

The secret to exerting the maximum lifting force and the maximum lifting height on a load is to make sure that the position of the bag is as close to the underside of the load as possible prior to starting the lift.

9.5.4 Increasing Lifting Height And Forces

If you stack two bags together you must remember that the maximum lifting capacity is that of the smallest bag used. However you will get the additional height using two bags.

Under no circumstances should you use more than two bags. If using two bags the smaller bag must be placed on the top.

It must be remembered that as the bags approach full inflation the load may become unstable. For this reason it is advised not to inflate the bottom bag to more than the 50% to 75% of its rated capacity. This will then create a pillow for the top bag to rest in.

To increase lifting forces, two bags can be place side by side.

9.5.5 Preparation And Positioning Of Air Bags

When you arrive at the scene proceed to make sure that you have gathered all the necessary gear and rigging required for the lift or that you have the availability of getting the material. This equipment would include air bottles and blocking or cribbing.

At the scene:

- Assess the scene, make sure it is safe for the team and the causality.
- Stabilize the object in the position found before any work commences. Block or crib it, chock it, set the brakes, etc.
- Build a crib for the lifting bags. The closer the bag is to the load the more effective it will be.
- When placing the bags make sure that the bag is protected from being damaged, marred or cut by the load or what it is sitting on.
- As the load is being lifted make sure the load is being cribbed or blocked so that if the load drops it will not drop more than the thickness of the bag.
- All blocking must be stacked, cribbing style to create a stable base so that if the load shifts slightly the cribbing will not topple over. To ensure a stable base the cribbing should not be stacked higher than it is long.
- The top level of any blocking or cribbing where the air bag will sit must be a solid deck or platform.

Figure 9.4 Lifting Truck By Axle

Figure 9.5 Lifting Truck Using The Box

9.6 Electronic Gas Detection – How Does It Work?

Emergency response crews face two basic challenges when entering dangerous environments. They need to know if the air is acceptable for normal, unprotected breathing and safe from potential explosions. Portable multigas detectors can help meet this challenge.

9.6.1 The Basics

Portable multigas detectors come in many styles and configurations. In most cases, they can simultaneously detect three to five gases and alert the user when the gas exposure level becomes a concern.

These detectors consist of multiple sensors in a single case. The electronics then change the sensor output into a numerical display showing the level of gas exposure. There are four basic types of portable gas sensors:

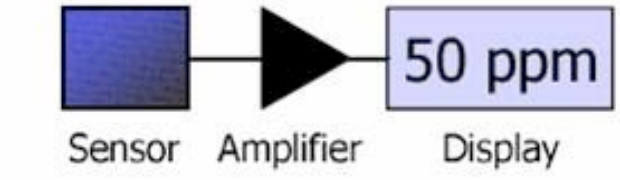

Figure 9.6 Basic detector operation

- Catalytic
- Electrochemical
- Infrared
- Photo Ionization Detectors

These sensors operate in different ways to enable them to detect certain gases. The two most common sensors are the catalytic and electrochemical sensors. Catalytic sensors detect flammable gases and electrochemical sensors detect many toxic gases. Infrared sensors and PID sensors are designed to detect either special gases or especially low gas levels, which cannot be detected by the other two technologies. We will look at only the catalytic and electrochemical sensors.

9.6.2 How Catalytic Combustible Sensors Work

To detect flammable gases, a heated wire is used. Basically, a special wire coil is heated by applying power to it.

The wire filament is selected or specially treated so that the surface will react and will readily burn (oxidize) gases that come in contact with it. If this coil is exposed to combustible (oxidizable) gases, the gas molecules react on the wire surface. This reaction releases heat and increases the temperature of the wire. As the wire temperature increases, the electrical resistance of the wire increases and is measured by a simple “Wheatstone Bridge” circuit which accurately measures this change. The result is then converted to a display reading on the face of the instrument (see Figure 9.7).

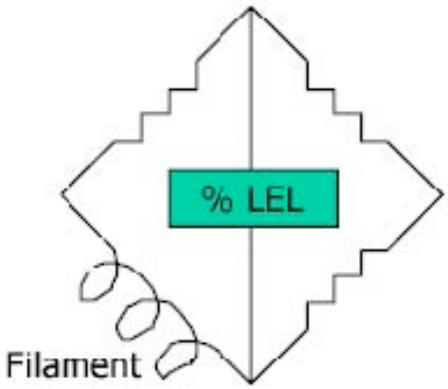

Figure 9.7 Combustible gas circuit

Since the catalytic combustible gas sensors act like small heaters, they use a lot of power and regularly require fresh or recharged batteries for the combustible gas detector. To increase sensitivity and reduce power consumed by these sensors, many manufacturers form a ceramic bead around the wire coil. This bead is also treated with special chemicals to make it more reactive. The bead increases sensitivity by providing more surface area for the reaction to occur.

9.6.3 Explosive Limits

Generally, for flame to occur, the fuel must be in a gas form to mix with air (the oxygen source). For instance, with gasoline, the liquid does not burn but the vapor given off by the liquid creates a dangerous situation. If a liquid does not give off enough vapors, it will not burn easily under normal conditions.

In general, any flammable substance with a flashpoint (the minimum temperature at which a liquid gives off vapor in sufficient concentration to ignite) of less than 100°F may be detected. Liquids such as diesel and jet fuels, have high flashpoints and cannot be readily detected by catalytic sensors since they do not give off enough vapors at normal temperatures to support combustion.

Too much gas can also displace the oxygen in an area and fail to support combustion. Because of this, there are limits at both low-end and high-end gas concentrations where combustion can occur. These limits are known as the Lower Explosive Limit (LEL) and the Upper Explosive Limit (UEL). They are also referred to as the Lower Flammability Limit (LFL) and the Upper Flammability Limit (UFL). Figure 9.8 graphically demonstrates these limits relative to gas concentration.

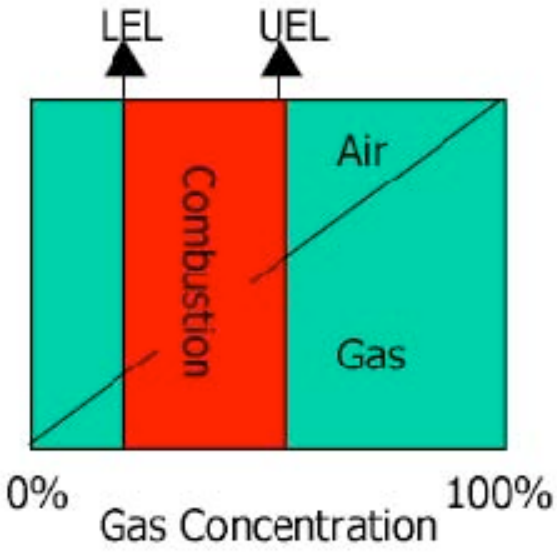

Figure 9.8 Lower & upper explosive levels

To sustain combustion, the correct mix of fuel and oxygen (air) must be available. The LEL indicates the lowest quantity of gas which must be present for combustion and the UEL indicates the maximum quantity of gas. The actual LEL level for different gases may vary widely and are measured as a percent by volume in air.

Most combustible gas instruments measure in the LEL range and gas readings are shown as a percentage of the LEL. For example: a 50% LEL reading means the sampled gas mixture contains half the gas necessary to support combustion.

9.6.4 Combustible Gas Response Factors

Catalytic combustible gas sensors can detect a wide variety of potentially flammable gases. From natural gas leaks to gasoline spills, this sensor is very good at helping to determine if there is danger.

However, it should be noted that different combustible gases react at different rates with the sensor. For instance, the same “%LEL” levels of two common flammable gases such as methane and pentane will yield different sensor outputs and different readings on the instrument display. To ensure an appropriate response on average, a mid-range response gas such as pentane is often used for calibrating the instruments.

Figure 9.9 shows four typical flammable gases and the resulting displays of a combustible gas detector calibrated to read pentane. There is a wide variation in the typical catalytic sensor response to these gases. Since you do not know what you will be called on to detect, the most common approach is to select a "middle-of-the-road" gas, such as pentane, as your calibration gas.

Gas Type	Actual % LEL	Actual Gas Concentration	Typical Display Reading (%LEL)
Pentane	50%	0.70%	50%
Methane	50%	2.50%	100%
Propane	50%	1.05%	63%
Styrene	50%	0.55%	26%

Figure 9.9 Comparison of actual LEL & gas concentrations with typical gas instrument readings

However we are fairly confident that the most common explosive gases in mine rescue work are methane, carbon monoxide and hydrogen sulfide so for our purpose, methane would be the calibration gas we most commonly use.

9.6.5 Electrochemical Toxic Gas Sensors

In addition to detecting combustible gases, multi-gas instruments can help determine if the atmosphere is acceptable for breathing. These instruments can answer two basic questions:

1. Is there enough oxygen present for me to breathe? and
2. Are there any other toxic gases present which can harm me?

Once again, portable gas detectors can handle the majority of common air-monitoring situations. Many can be ordered with a combustible sensor, an oxygen sensor and up to two or three toxic gas sensors, depending on your application.

9.6.6 How Electrochemical Toxic Gas Sensors Work

Toxic gas sensors measure one type of gas at a time. Toxic gases most commonly encountered on the job are carbon monoxide (CO) from mobile equipment exhaust, oxides of nitrogen (NO_2) again from mobile equipment exhaust, or possibly sulphur dioxide (SO_2).

An electrochemical sensor is similar to a small battery. One chemical component required to produce the electric current is not present in the sensor

cell. The target gas, such as CO, diffuses into the membrane at the top of the sensor. The CO then reacts with the chemicals on the sensing electrode and generates an electrical current to be measured and displayed as in Figure 9.10. If no CO is present, no reaction occurs and no current is generated.

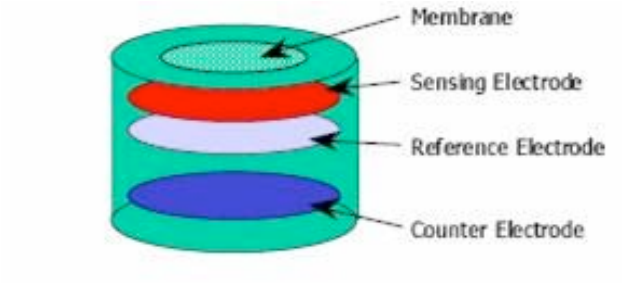

Figure 9.10 Electrochemical toxic gas sensors basic construction

Electrochemical sensors are typically available for a wide variety of gases, from carbon monoxide to chlorine.

9.6.7 Oxygen Sensors

Oxygen sensors operate on the same basic principles as other electrochemical sensors. Oxygen from the air diffuses into the sensor and reacts to produce an electrical current. Typically, oxygen sensors use the oxidation of lead as the basis for their detection. As lead is consumed (oxidized), sensor life diminishes.

Our surrounding atmosphere contains an average of 20.9% oxygen. Since oxygen is present in the air at all times, oxygen sensors are slowly being consumed, even as they sit "unused". Manufacturers are responding by slowing the reactions in the sensors. Just a few years ago, these sensors typically lasted a year; some now last well over two years.

Although you may want to place your oxygen sensor in a box containing no oxygen to increase the life of the sensor, this may damage your sensor permanently. Be sure to follow the manufacturer's instructions on proper storage for your instruments.

9.7 Review Questions

1. You have finished a mission and you are feeling agitated, wound up, depressed or drained, what are some effective methods to deal with the post incident stress?

2. How is a critical incident defined?

3. You have been involved in a critical incident and you are still not feeling right after a period of time, what should you do and how long after the incident do you wait?

4. What is the biggest advantage of air bags have over hydraulic jacks?

5. When using pneumatic lifting bags, how is the maximum lifting force and the maximum lifting height applied to the load?

6. With respect to stacking lifting bags in order to increase lifting height, what must be done?

LEARNING OBJECTIVES AND TARGET AUDIENCE

SECTION 10
INTRODUCTION TO BREATHING APPARATUS & SPECIAL PROCEDURES FOR THE BG 4

Learning Objectives

Section 10 is intended for information on the introduction to using breathing apparatus and procedures to be used with the BG 4 in mine rescue, which are not covered in the Draeger BG 4 user manuals.

Suggested Target Audience

Section Number	Topic	Basic Mine Rescue Trainees	Standard Mine Rescue Trainees	Advanced Mine Rescue Trainees	Mine Rescue Equipment Technicians	Mine Rescue Instructors	Director of Operations & Resource Personnel	Senior Management Personnel	Supervisors	New Or Transferred Employees
10.1	Introduction To Breathing Apparatus	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
10.2	Emergency Procedures With The BG 4	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
10.3	Collapse Of A Team Member	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
10.4	Member Is Low On Oxygen	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
10.5	Using the BG 4 As A Resuscitator	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
10.6	Cycle Breathing To Extend The Life Of A BG 4	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			
10.7	Long Duration Prior To Cleaning Of The BG 4 Procedure	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**				
10.8	Oxygen Cylinder Safety Cap	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**				
10.9	Review Questions	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**			

Section 10. INTRODUCTION TO BREATHING APPARATUS & SPECIAL PROCEDURES FOR THE BG 4

10.1 Introduction To Breathing Apparatus

As a mine rescue member you will be required to learn the operation and maintenance of the CCBA Draeger BG 4 which is the unit of choice for Manitoba. You must also know there are other types of breathing apparatus in the rescue business.

The mine rescue teams use oxygen supplied units while fire fighters use an air supplied apparatus.

As stated above you will be required to know and use the BG 4. There is vital information for all types of breathing apparatus.

It is important to learn to breathe properly when you wear and use a breathing apparatus. Breathing slowly and deeply will provide the most efficient operation of the breathing apparatus.

The unit must be tested for function of working parts and air tightness before donning the apparatus.

Although the apparatus renders the wearer completely independent of the outside air, it cannot protect you from poisonous gases absorbed through the skin.

10.2 Emergency Procedures With The BG 4

The Manitoba Mine Rescue Organization acknowledges the following procedures are not recommended by the manufacturer, but recognizes under extreme circumstances drastic measures may be required.

Prior to using these emergency (life saving) procedures, the mine rescue team members must exhaust all other available options.

Manitoba Mine Rescue personnel must be familiar with and be able to implement these life saving procedures if necessary.

10.3 Collapse Of A Team Member

There may be a time in a mission when a team member collapses. This may be a result of CO2 buildup in the apparatus, over exertion, breathing too hard and fast or may be the result of exposure to high heat.

In order to assist the collapsed team member, check the apparatus first to make sure that it is functioning properly. Perform first aid and use the following procedure;

1. Check the display to make sure there is oxygen in the cylinder. Change out the oxygen cylinder as per the procedure 10.4.
2. Check the facepiece seal by removing the apparatus cover. Block the breathing bag plate from contacting the relief port, filling the breathing bag by bumping the manual bypass and then putting gentle pressure on the breathing bag. Never open the manual bypass wide open or use full pressure on the breathing bag while someone is wearing the facepiece, as it will cause considerable respiratory discomfort. There should be a firm resistance to the pressure put on the bag. The facepiece should also rise from the face. Little or no resistance, would indicate there is a poor seal. Readjust the facepiece to maintain a seal.
3. If there is a good seal, activate the relief valve with one hand and press the breathing bag flat with your other hand to empty the breathing bag. This occurs through the relief valve.
4. Once this has been done, allow the relief to close and use the bypass to gently refill the breathing bag. Watch the breathing bag for movement to make sure that the person is breathing. (*Note: If they are not breathing you may have to use their apparatus as a resuscitator as described in Section 10.5.*)
5. It then may be necessary to empty the breathing bag again and then refill it with fresh O_2 because of possible CO_2 buildup.
6. Once the member has regained his composure he will need to rest before the team returns to fresh air.

10.4 Member Is Low On Oxygen

When it becomes apparent a mine rescue team member's oxygen supply is depleted more rapidly than other team members, the captain must make the decision to return to fresh air.

Some reasons for the low level of O_2 may be:

- Breathing too rapidly
- A leak in the apparatus
- Excessive use of the manual bypass
- Excessive use of the minimum valve
- A high litre flow

If the member is low or out of O_2, use the following procedure to change out the member's O_2 cylinder:

1. Remove the back cover and inspect the apparatus for problems.
2. Use the manual bypass to fill the breathing bag.
3. Shut off the O_2 cylinder and use the bypass to bleed off pressure.
4. Once line is bled off remove the cylinder and replace with spare cylinder.
5. Advise the member prior to turning on the oxygen.
6. If a problem is not found, the cover should be left off and another member assigned to follow the member with the problem in order to observe the machine and breathing bag.

10.5 Using The BG 4 As A Resuscitator

A BG 4 can be used to perform artificial respiration.

When you use the apparatus for a resuscitator you must make sure the facepiece has a proper seal, the hoses are not kinked and there are no obstructions to the patient's breathing. The patient's airway must be maintained in an open position.

The procedure:

1. Remove back cover of apparatus and then make sure you have a good facepiece seal on casualty. Confirm you have an open airway.

2. Remove springs & block the breathing bag plate from contacting the relief valve, fill the breathing bag using the manual bypass, and gently press down on the breathing bag. This will force the oxygen into the patient's lungs. Watch for the chest to rise. Do not over fill the patient's lungs as they could vomit. You will be able to feel the increased resistance when the lungs are full.
3. Release the pressure from the breathing bag. The release of the pressure will act as an exhalation cycle.
4. Repeat this cycle approximately 12 to 14 times a minute. (Your own breathing cycles can help time the cycling for the patient.)
5. Refill the breathing bag as necessary.
6. When the patient begins to breathe on his own, monitor his breathing and observe his vitals and watch for nausea and tremors. If he does vomit remove the facepiece immediately and clean it out and replace it on the patient. *Practice proper first aid procedures*.

It must be remembered a patient may be found a considerable distance from fresh air and because of the atmospheric conditions or the nature of the emergency, the patient's life may be at stake. This situation requires a team to take immediate action in order to save the patient's life.

In order to become proficient in this method of resuscitation a team must practice it regularly.

10.6 Cycle Breathing To Extend The Life Of A BG 4

The following procedure to extend the life of the BG 4 requires the strict discipline and careful monitoring by team members.

1. When a team decides the situation requires them to extend the life of their apparatus, they should find a safe place where they can sit down and get comfortable.
2. The BG 4 is difficult to remove from your back. To take the apparatus off your back, unbuckle the hose retaining straps on the shoulder straps to release the hoses. Without removing the facepiece, remove the apparatus as if it is a jacket. Pass the off side hose over your head. Place the apparatus in front of you and turn it around with the back cover facing you or towards you. This movement should un-kink

the hoses. Put it down where you can monitor the breathing bag. You could also leave the apparatus on your back but if this is done, personnel must maintain a position so another member can monitor the functioning of the apparatus.

3. Remove the cover and take out the breathing bag springs (If the springs are left in the machine can go into alarm). Fill the breathing bag using the bypass valve. Be very careful not to over fill the breathing bag causing the relief valve to open and allow the valuable O_2 to escape to the atmosphere, thus further shortening the usable life.
4. Shut off the cylinder valve.
5. Each person is responsible to monitor their own machine. When the breathing bag deflates you will experience increased resistance and the mask will suck in on inhalation. You will have to open the cylinder valve in order to refill the breathing bag. Open the cylinder valve, use the bypass to fill the bag (be careful not to fill to the relief) and then close the valve.

Tests have shown that, under ideal conditions and beginning the test with a cylinder with 3,000 psi of Oxygen, it is possible to extend the life of the apparatus for up to 18 hours. With a cylinder with 2,000 psi, it could last 10 hours.

The time a person can breathe from the breathing bag with the cylinder shut off will vary with each individual.

> Note: There will be an increased resistance to breathing, since you have removed the springs it now turns the apparatus into a demand type of apparatus from a positive pressure apparatus. The unit will give alarms if the springs are not removed. The bodyguard can be shutoff while breathing down the bag which will conserve the battery power. The bodyguard will restart each time the oxygen cylinder valve is opened when the length of service life is increased using the method described above.

Removal of the battery from the bodyguard will shut it down completely thus eliminating the alarming. The downside of this is that you will not be able to monitor the oxygen pressure.

10.7 Long Duration Prior To Cleaning Of The BG 4 Procedure

In circumstances where there is a long interval between the time a BG 4 is used (transport, lag times) cleaned and serviced, the following procedure will apply;

The yellow line from the pressure reducer to the minimum valve must be disconnected. This can either be done at the reducer or minimum valve as shown in pictures below.

Figure 10.1 Remove Yellow Line From Pressure Reducer

Figure 10.2 Remove Yellow Line From Minimum Valve

Figure 10.3 Remove The Blue Line At The Cooler Box

These lines are removed to reduce the possibility of moisture getting back into the pressure reducer and electronics during this long interval.

The general practise should be to remove the yellow line from the pressure reducer and the blue line from the air cooler while in the vertical position (before laying down). The method of transport (vertical or horizontal) will not matter with these lines disconnected. *From Greg Trahan – Draeger Tech III & Trainer*

10.8 Oxygen Cylinder Safety Cap

There is a safety cap located on the valve on the top of the cylinder. This cap has a bursting disk in it. The disk is there to protect the cylinder from over pressure due to exposure to excessive heat or oxygen over pressure during filling. The disk is designed to fail at 4000 lbs pressure. When this occurs the entire cylinder will drain in a very short period of time. Sudden and complete failure of the disk will be accompanied by a loud bang like a gunshot and a shrill shriek or whistle as the cylinder empties. A leak at the bursting disk will deplete the bottle even when the cylinder is closed. A leak from the safety cap or bursting disk is easily diagnosed by immersing the valve in water and observing for bubbles.

10.9 PSS BG 4 Pre Use Inspection

Once members have drawn their equipment they must follow the following pre use inspection.

1. Check Tamper seal (must be within six months from last station test)
2. Harness and hoses (visual check)
3. CO2 absorbent canister (visual check)
4. Oxygen cylinder connection (visual check)
5. Connections (visual check)
6. High pressure leak test (ocr – open cylinder valve / ccr – close cylinder valve)
7. Test warning alarms (ocr – open cylinder valve / ccr – close cylinder valve)
8. Cylinder pressure
9. Battery condition
10. Don the unit
11. Face piece inspection (lens, straps, mask body, connection)
12. Leak test face piece
13. Anti fog
14. Install ice
15. Report to Captain

10.9 Review Questions

1. What two critical tests are performed on a breathing apparatus?

2. Describe how a person should breathe when wearing a breathing apparatus with a face mask.

3. What devices can be used for protecting people from an atmosphere contaminated by toxic or noxious gases?

4. Describe what a self-contained breathing apparatus is and how it can protect you.

5. What types of gases do self-contained breathing apparatus not protect you from?

6. What type of apparatus should be worn in an oxygen depleted atmosphere?

7. If you were a mine rescue team captain and your gas detection equipment indicated a high reading of a toxic gas, such as SO_2, CO, or NO_2, what would you do?

8. A team member's face piece seal has been compromised and his oxygen cylinder is dangerously low. What are the six steps to replace his cylinder in a contaminated atmosphere?

9. When using the BG4 to apply artificial respiration, do you plug the drain valve before pressing on the breathing bag?

10. When using the "cycle breathing" technique, how long could you extend the life of the BG 4 with a cylinder pressure of 2,000 pounds per square inch (psi)?

11. When using the "cycle breathing" technique to extend the life of the BG 4,

what part must be removed?

12. When there is an extended period of time between the time a BG 4 is used and before it is properly cleaned, what must be done to the unit?

13. One atmosphere is approximately equal to how many psi?

14. Match the following definitions on the left with the correct answer on the right;

a) SCBA	___Re-circulates exhaled air and makes it safe for re-breathing by removing carbon dioxide and adding oxygen.
b) Combustible	___To suffocate or choke
c) Ignite	___Team scheduled to be ready at the FAB to assist or replace a team in the field.
d) Reserve team	___Apparatus that supplies oxygen to the wearer during inhalation only
e) Demand type	___To set on fire.
f) Closed Circuit BA	___Harmful to health
g) Noxious	___Expels all of the exhaled air and provides fresh air
h) Back up team	___Provides a continual small supply of air and additional air during inhalation
i) Asphyxiate	___Team in a state of readiness to replace the back up team.
j) Open circuit BA	___Self contained breathing apparatus
k) Pressure demand BA	_____Capable of burning, flammable

15. How would you test the oxygen cylinder and the valve for air tightness?

16. What is the purpose of the safety nut on the cylinder valve & how does it do this?

The following questions are specific to the BG 4; most answers will be found in Draeger BG 4 User Manual.

1. What are the major component groups of the BG 4?

2. Is it permissible to use the BG 4 for diving?

3. Briefly explain the flow of the BG 4. Beginning with the exhalation valve.

4. Is there a situation where it would be permissible to operate the BG 4 breathing apparatus without an ice block?

5. What type of breathing apparatus is the BG 4?

6. List 10 features of the PSS BG 4 Sentinel.

7. What is the electronic monitoring system comprised of?

8. What is the lowest temperature that the BG 4 is approved for use at?

9. Briefly describe the procedure when getting under oxygen with a BG 4?

10. What lubricant does Draeger recommend for use on O-rings?

11. At the end of the self test sequence the following icons will be displayed

    a. If the tally is removed:

    b. If the tally is installed:

12. List the necessary steps for field testing the BG 4 and getting under oxygen.

13. How does the PSS BG 4 report a system fault?

14. What should be done when battery warning “1” is displayed at the conclusion of a Sentinel function test?

15. When the oxygen cylinder is turned on, the Sentinel will perform a self-test, a battery test and then offer to do a high-pressure leak test. What will happen if the operator does not initiate the high-pressure leak test?

16. What procedure should be followed if the low pressure warning alarm sounds when a fully charged oxygen cylinder is opened?

17. What is the procedure for performing a seal test after donning the face piece of the BG 4?

18. What message will be displayed after pressing the left hand button on the bodyguard for longer than three seconds?

19. What is the purpose of the bypass valve?

20. How often should you check your oxygen pressure on the BG 4?

21. Pressing the right hand button on the bodyguard will change the display from what to what?

22. What icon is displayed following the minutes to 55 bar alarm?

23. If the tally is removed and the motion sensor detects no movement of the unit, how long will it be before it goes into pre-alarm?

24. If there is no motion detected after the pre alarm activates, how much time

elapses before the unit will go into full alarm?

25. What warning indicators and alarms occur when your unit is low in oxygen?

26. What three disinfectants does Draeger approve for cleaning the BG 4?

27. What is the purity of oxygen used in the BG 4?

28. What is the constant dosage range for the BG 4 breathing apparatus?

29. What is the shelf life of an original sealed container of carbon dioxide absorbent – Dragersorb 400?

30. When a container of carbon dioxide absorbent – Dragersorb 400 has been opened, how long is it good for?

31. What is the shelf life of the carbon dioxide absorbent – Dragersorb 400 once it has be decanted into the regenerative canister?

32. What is the pressure in a fully charged oxygen cylinder used in the BG 4?

33. How often do BG 4 oxygen cylinders require hydrostatic testing?

    a. Steel cylinder –

    b. Carbon fiber cylinder –

34. What should a mine rescue person do when a malfunction occurs during a field test?

35. Why is it dangerous for pressurized oxygen to come near oil, grease or similar contaminants?

36. Why should oxygen cylinders be opened slowly?

37. Why should empty oxygen cylinders be closed?

38. The minimum valve should open at a value between?

39. The constant metering quantity should lie between?

40. The opening pressure of the relief valve should lie between?

41. When should the high-pressure leak test be carried out?

42. To what pressure does the reducing valve reduce the oxygen?

43. When the manual by-pass valve is used, what volume of oxygen is dispensed?

44. What is the purpose of the Sentinel display unit & what does it display?

45. What is the capacity of the breathing bag?

46. What is the volumetric capacity of the oxygen cylinder?

47. What is the compressed oxygen supply of the bottle?

48. What oxygen cylinder pressure is required to complete the high-pressure leak test?

49. How should you refill the regenerative cartridge with Dragersorb 400?

50. Why should a facemask wiper blade be moistened with KlarPilot or similar product?

51. How should the facemask be cleaned and stored?

52. List two types of CO_2 absorber cartridges.

53. What is the function of the cartridge?

54. What is the required oxygen cylinder pressure for four hour use?

55. List the dangers associated with a leaking facemask.

56. Why are oxygen self-contained breathing apparatus equipped with a by-pass valve?

57. When retreating with a machine that has a faulty pressure reducer, why should the by-pass valve not be kept open?

58. What is the function of the breathing bag on a closed circuit breathing apparatus?

59. How far should the cylinder valve be opened?

60. What causes high oxygen consumption on the BG 4?

61. What tests can be performed on the BG 4 utilizing a RZ 25 Universal tester or Test It 6100?

62. How often must the BG 4 pressure reducer assembly be rebuilt and recertified?

Glossary of Terms

Airflow	The amount of air moving through a mine opening; usually measured in m3/s (cubic metres per second) or cfm (cubic feet per minute).
Air Lock	A system of doors or seals to permit passage of personnel and/or vehicles, without permitting appreciable airflow.
Airway	Any passage through which air is flowing.
Anemometer	Instrument used for measuring medium and high velocity air currents in the mine.
Asphyxiate	To suffocate or choke.
Atmospheric Pressure	Force exerted by air. Atmospheric pressure is measured on a barometer and is one bar at sea level. 1 atmosphere equals 14.74 psi.
Auxiliary Fan	A portable fan used to supplement the ventilation of an individual working place.
Backup Team	Rescue team stationed at the fresh air base ready to move in as a "back up" for the working team beyond the fresh air base. They are also the next working team. (see standby team)
Brattice	A material used in building seals or used to redirect the air flow in a workings of a mine. Usually made of burlap.
Briefing	Session held before a team goes underground to inform them of known conditions underground and give them a work assignment.
BTU	British Thermal Unit – the amount of heat required to raise the temperature of 1 pound of water by 1° F.

Bulkhead	A wall or partition constructed across a passageway to direct the ventilating air in its proper course.
CAS	Chemical Abstract Services – organization that sets the unique numbers to chemicals (ie: Carbon Monoxide….630-08-0).
Chain of Command	Order of authority and division of responsibilities among personnel during a rescue and recovery operation.
Closed Circuit Breathing Apparatus	An apparatus that re-circulates exhaled air and makes it safe for re-breathing by removing the carbon dioxide and adding fresh oxygen.
Combustible	Capable of burning; flammable.
Command Centre	Head quarters for the rescue and recovery operation.
Contaminant	Something which fouls or causes air to become impure.
Contaminated	Air that is unfit for breathing.
Corrode	To eat away gradually.
Debriefing	Session held when a team returns after completing an assignment to review what they saw and did.
Demand Type Breathing Apparatus	An apparatus that supplies air or oxygen to the wearer during inhalation only and has negative pressure within the face piece.
Exhaust	The air course along which the ventilated air of the mine is returned or conducted to the surface.
Exhaust Air	The air that has passed through all the working areas and is on the way out of the mine.
Explosive Range	The range of concentrations within which a gas will explode if ignited in air. (expressed in percentages).

Fresh Air Base	Base of operations from which the rescue and recovery teams can advance into contaminated atmospheres.
IDLH	Is a condition that poses an immediate threat to life or health or a condition that poses an immediate threat of severe exposure to contaminants such as radioactive materials which are likely to have adverse cumulative or delayed effects on health.
Incipient Stage Fire	This is a fire in its beginning stage, which can be controlled with a portable fire suppression device such as a fire extinguisher or small water hose system.
Ignite	To set on fire.
Inert	Not readily reactive with other chemical elements; forming few or no chemical compounds.
Intake	The passage through which fresh air is drawn or forced into a mine or to a section of the mine.
Link-line	Used in smoke, about two meter long with snaps on each end. Carried by each team member so that members can be linked together when smoke is encountered.
Negative Pressure	Pressure less than normal atmospheric pressure, creating partial vacuum.
Noxious	Harmful to health.
Open Circuit Breathing Apparatus	An apparatus that expels all of the wearer's exhaled air and provides the wearer with fresh air to breathe.
Positive Pressure	Pressure greater than normal atmospheric pressure.
PPM	Parts per million.

Pressure demand Breathing Apparatus	An apparatus that provides a continual small supply of air to the face-piece, as well as additional air when the wearer needs it during inhalation. This type of apparatus has positive pressure in the face-piece.
Pyrolysis	Is the chemical decomposition of a substance through the action of heat.
Reserve Team	Team in a state of readiness to replace the backup or standby team in the rotation schedule.
Rotation Schedule	Schedule that establishes a clear order of team usage during a rescue and recovery operation.
SCBA	Self Contained Breathing Apparatus.
Service Time	The length of time an apparatus is approved to be used per wearing.
Smoke	Tiny particles of solid and liquid matter suspended in air as a result of combustion.
Smoke Tube	Instrument used for measuring low-velocity air currents in the mine.
Solubility	Ability to dissolve in water.
Specific Gravity	The weight of a gas compared to the weight of an equal volume of air under the same temperature and pressure.
Standby Team	Team scheduled to be on surface or underground fresh air base in ready reserve when rescue work is going on underground. (see backup team)
STEL	A 15 minute TWA exposure which should not be exceeded at any time during a work day even if the 8 hour TWA is within the TLV-TWA.

Tetrahedron	Four sided geometric figure representing the four components required to maintain combustion.
TLV	Threshold limit value. An average concentration of a substance to which a person may be exposed seven to eight hours a day without adverse effect.
TLV – Ceiling	The concentration that should not be exceeded during any part of the working exposure.
Velocity	Rate of airflow in meters per minute.
Velometer	Instrument used to determine the velocity of air currents.

Metric Conversions

To Convert	Into	Multiply by
atmospheres	bars	1.01325
atmospheres	inches of mercury	39.92
atmospheres	pounds/sq. in.	14.70
bars	atmospheres	0.9869
bars	pounds/sq. in.	14.50
BTU	kilogram-calories	0.2520
centigrade	Fahrenheit	$(C^{o}x9/5)+32$
centiliter	cubic inch	.6103
centimeters	inches	0.3937
centimeters/sec.^{2}	feet/sec.^{2}	0.03281
cubic centimeters	cu. feet	3.531×10^{-5}
cubic centimeters	cu. inches	0.06102
cubic feet	liters	28.32
cubic feet/min	cubic meters/sec	.0005
cubic inches	liters	0.01639
cubic meters	cu. feet	35.31
cubic meters	cu. yards	1.308
cubic meters/sec	cubic feet/min	.002
cubic yards	cu. meters	0.7646
cubic yards	liters	764.6
feet	centimeters	30.48
feet	meters	0.3048
feet/min.	meters/min.	0.3048

To Convert	Into	Multiply by
gallons imp.	litres	4.5459
gallons (U.S.)	litres	3.785
gallons (U.S.)	cu. Meters	3.785×10^{-3}
grams	ounces (avdp)	0.03527
inches	centimeters	2.540
inches of mercury	atmospheres	0.03342
kilograms	tons (short)	1.102×10^{-3}
kilometers	feet	3,281
kilometers	miles	0.6214
Liters	cu. feet	0.03531
Liters	cu. inches	61.02
meters	feet	3.281
meters	inches	39.37
miles (statute)	meters	1.609
ounces	grams	28.349527
ounces (fluid)	liters	0.02957
pounds	grams	453.5924
pounds	kilograms	0.4536
quarts	liters	0.9463
square centimeters	sq. inches	0.1550
square feet	sq. meters	0.09290

To Convert	Into	Multiply by
square kilometers	sq. miles	0.3861
square meters	sq. feet	10.76
square meters	sq. yards	1.196
square miles	sq. km.	2.590
square yards	sq. meters	0.8361
temperature(^{o}F)	temperature (^{o}C)	-32 X 5/9
tons (metric)	pounds	2.205
tons (short)	tons (metric)	0.9078
yards	meters	0.9144